SLEEP PATTERNS AND PHYSIOLOGICAL MARKERS OF STRESS IN GRADUATE PARAMEDICS

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Declaration of Originality

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Statement of Ethical Conduct

The research associated with this thesis abides by the international and Australian codes on human experimentation and the rulings of the Safety, Ethics and Institutional Biosafety Committees of the University. Ethical approval was granted by the Tasmanian Health and Medical Human Research Ethics Committee on 11th September 2015 (reference number H0015110).

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Abstract

Introduction / Aims

New graduates are entering the paramedic workforce in Victoria in unprecedented numbers, undertaking shift work patterns that are known to be a risk factor for a raft of major medical conditions. Whilst most research in the healthcare field examines hospital-based staff, limited research is available that examines new recruits within the emergency medical response field and how they adapt to shift work. This study has assessed graduate paramedics during the initial five months of rotational shift work, aiming to identify if the quality and quantity of sleep is altered during this period of rotational shift work and if early risk factors of cardiovascular disease and metabolic disorders manifest during this initial exposure to shift work.

Methods

Graduate paramedics commencing employment with Ambulance Victoria were assessed over a 25-day block before starting shift work (Baseline), and during their 1st and 5th month of shift work. In each block, sleep and activity level was recorded 24-hours a day using a wrist-worn actigraph device. Subjects also maintained a sleep log each morning and completed regular subjective sleep questionnaires. From this, Sleep duration - the number of hours/minutes scored as ‘asleep’ - was established. Sleep Efficiency was calculated as a

percentage of time spent asleep from the time spent in bed. The number of awakenings (NoA) and the Wake After Sleep Onset (WASO) for each sleep period were recorded as an indication of sleep quality. Total sleep time (TST) for the 25-day period was also tallied and recorded in hours and minutes for each assessment. Data was compared across each assessment period using the 25-day average, during shift work and during RDOs. Further assessments of general health and well-being, including height, weight, waist circumference, resting heart rate, blood pressure, fasting blood glucose, body composition, aerobic fitness (step test), and subjective stress questionnaires were also conducted at the commencement of the Baseline period, at the conclusion of shift work Month 1, and pre- and post- shift work Month 5.

Results

28 participants (13 male and 15 female) completed the full study protocol. A significant (p =0.046) increase in the total sleep time was observed across the 25-days of each month when shift work was undertaken. The number of sleep episodes recorded during these months of shift work also increased (p <0.005), however sleep efficiency did not differ significantly (p =0.17). The NoA recorded for the sleep episode after night duty was significantly less in Month 1 (p <0.005) and Month 5 (p <0.01) compared to Baseline. All sleep metrics recorded during RDOs were not different to Baseline with the exception of the night before returning to work, where there was a significant reduction in sleep duration (p <0.005). During shift work, self-reported poor sleep quality increased compared to Baseline (p <0.001).

A significant (p =0.0097) increase in the percentage of time spent sedentary was observed across the study protocol, coinciding with a significant (p =0.0026) decline in the percentage of time spent undertaking light exercise, but not moderate to vigorous physical activity (MVPA) nor the average number of steps recorded per day. No significant difference was observed in participants' weight (p =0.071), however waist circumference did increase significantly (p =0.008). No significant changes were noted for systolic (p =0.33) or diastolic (p =0.98) blood pressure, nor fasting blood glucose levels (p =0.64).

Discussion

The 25-day mean Sleep Efficiency remained the same throughout each assessment period, as did the RDO Sleep Efficiency recorded during the shift work phases of the protocol. Alterations in sleep patterns, necessitated by the rotational roster structure, influenced the 25-day mean data for WASO and NoA. However, when looking specifically at RDOs, there was no difference in measures of sleep disturbance compared to Baseline. A shorter Sleep Duration consistently observed on the final RDO suggests that paramedics are not well-rested for their first day back at work.

Overall sleep quantity increased during Month 1 and Month 5 of shift work, however sleep became more fragmented leading to an increased number of short duration sleep episodes. Short sleep has well established links to major medical conditions including diabetes, obesity, heart disease and Alzheimer's disease. Data showed increased amount of sedentary time, reduction in light exercise and increased waist circumference. This may indicate that early risk factors for major medical conditions are presenting in the first six months of ambulance work.

Conclusion

This study is the first quantifiable research to assess physiological changes in sleep patterns and activity levels of graduate paramedics undertaking a new career with shift work. The data suggests that shift work leads to more fragmented sleep patterns. What is not clear is the consequences on job performance and the long-term implications for paramedics' health. Subsequent research involving larger cohorts over longer time frames is needed to assess if alterations to sleep patterns persist over a paramedic's career or even beyond their ambulance service employment.

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1.1 Sleep

1.1.1 Physiological role of sleep

Even though most humans spend one third of their lives asleep (Hamet and Tremblay, 2006), and despite significant investigation, its exact purpose remains unclear. Research by Walker (2009) suggests that sleep is integral in "regulating effective brain function and emotional experience" (pg 192), and most sleep scientists now consider sleep to be an important tool in clearing away unneeded memories and making way for new learning each day (Diering et al., 2017). This seems to fit with developmental stages of life, where young children sleep for longer periods as their developing brains are learning much more than their adult counterparts (Roffwarg et al., 1966). Later in life, sleep declines and becomes fragmented as we have less of a need to learn new things (Coolidge et al., 2014). For early career professionals, when learning is vital for skill acquisition, acute sleep loss can reduce short term memory (Vedhara et al., 2000), impair cognition (Kim et al., 2007) leading to deterioration of work performance (Samkoff and Jacques, 1991), and increase the risk of chronic medical conditions or accelerated disease progression (Kecklund and Axelsson, 2016). Therefore, good quality sleep is vital during this period of intense learning and adaption to a new workplace.

1.1.2 Sleep architecture

In 1916, Austrian neurologist Constantin von Economo identified patients who presented with a type of viral encephalitis also went on to develop symptoms of disrupted sleep patterns (Triarhou, 2006). Although he was never able to identify the specific virus that caused the sickness, von Economo was able to identify areas of the brain in which lesions would cause alterations to the sleep-wake regulation of the body. Research over the past few decades has further expanded on von Economo's discoveries to identify the other neural controllers of the sleep-wake cycle. The suprachiasmatic nucleus (SCN) has been found to act as the "brain's master clock" (Saper et al., 2005), operating on a molecular feedback loop centred around the predictable variations of temperature and light across a 24-hour period (Kervezee et al., 2018). The SCN, controlled by light inputs during daytime from the retina and melatonin secreted from the pineal gland after dark, transmits information to peripheral tissues to direct a vast array of body systems. One of these systems, the sleep-wake cycle shown in Figure 1.1, aims to maintain sleep homeostasis by utilising melatonin and adenosine (Kervezee et al., 2018). Researchers have found that melatonin enhances nocturnal sleep and leads to higher alertness of individuals during daytime hours (Arendt and Skene, 2005, Lockley et al., 1995, Sack et al., 2000), while the accumulation of adenosine is proposed to maintain arousal during prolonged period of wakefulness (Basheer et al., 2000, Zhi-Li et al., 2011).

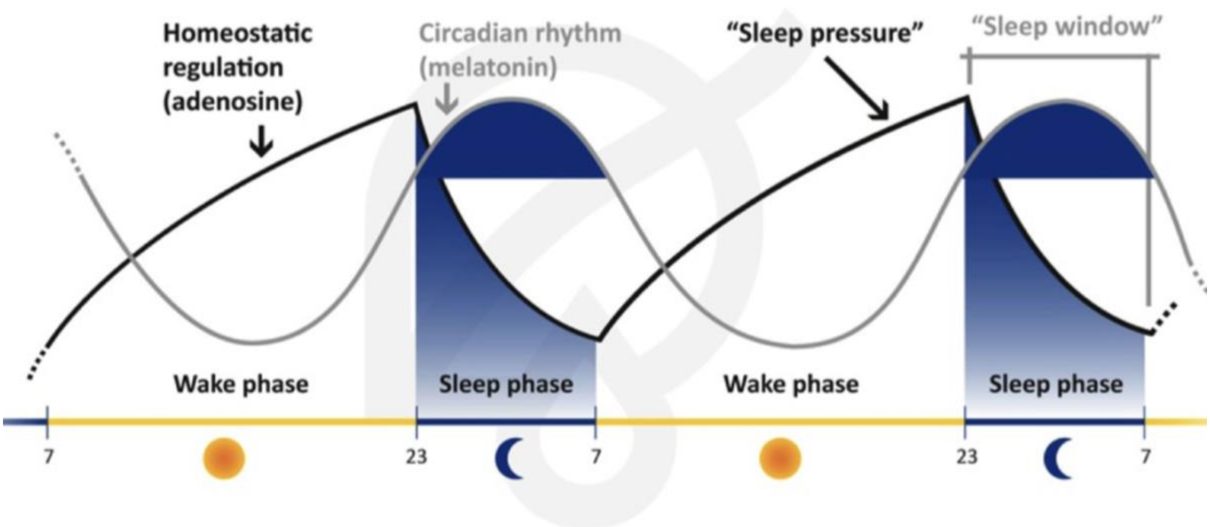

Figure 1.1: The typical sleep-wake cycle showing the influence of adenosine and melatonin (Faguet, 2018). Reproduced under Creative Commons Attribution 4.0 International License.

Von Economo also observed a smaller group of patients who found sleep difficult and could only sleep for a few hours each day. He was able to identify lesions of the anterior hypothalamus and basal ganglia in this cohort of patients (Saper et al., 2005), leading von Economo to theorise a ‘sleep part’ of the brain (Parkes, 2015). During the latter part of the twentieth century, scientists identified the ventrolateral preoptic nucleus (VLPO) which was primarily active during sleep (Sherin et al., 1996). The VLPO neurons were found to contain inhibitory neurotransmitters, primarily galanin and γ-aminobutyric acid (GABA) (Gaus et al., 2002). When activated, the VLPO neurons shut down the arousal systems which normally stimulate the cortex and promote waking states during sleep. Working alongside the VLPO is dorsal medial hypothalamus (DMH). This part of the brain integrates many cues before deciding if sleep is appropriate at that time. The DMH is the structure which will delay sleep despite the SCN saying “it’s bedtime”, an important consideration for shift workers functioning at unusual hours of the day (Saper et al., 2001).

A normal sleeping pattern begins with a period of non-rapid eye-movement (NREM) before progressing into the deeper sleep phase known as REM sleep (Carskadon and Dement, 2005). Across the sleep episode, periods of REM and NREM occur, as shown in Figure 1.2. NREM sleep is divided into stages of shallow and middle to deep sleep, and vary in duration. Each stage increases in the amount of stimuli required to arouse a person from sleep (Institute of Medicine (US) Committee on Sleep Medicine and Research, 2006).

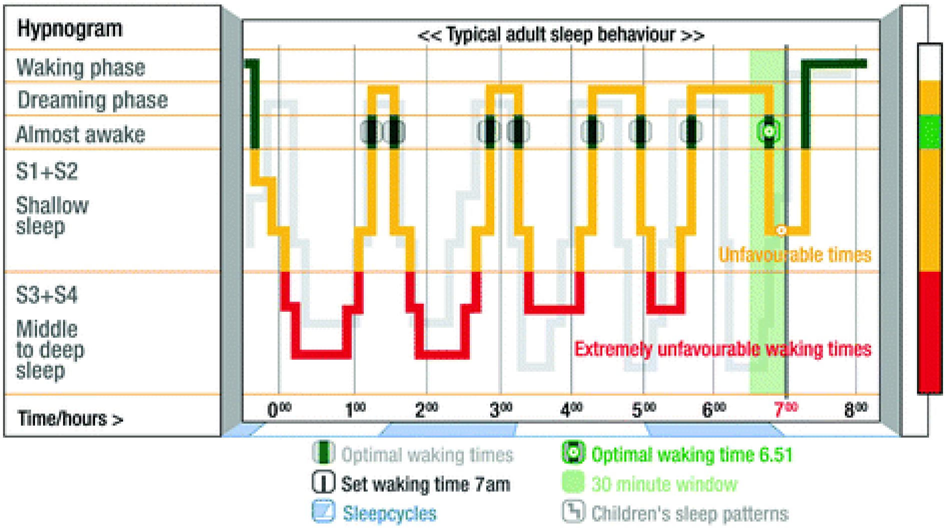

Figure 1.2: A typical 8-hour sleep pattern showing REM sleep and the 4 stages of NREM sleep (Ebermann and Murtha, 2013).

Dreaming has typically been associated with REM sleep, a state in which the body has decreased muscle tone and reflex response to prevent vivid dreams leading to involuntary movements (Dement and Kleitman, 1957). During REM sleep, neurons in the monoaminergic nuclei in the upper brainstem cease firing, leading to total muscle relaxation (Sherwood, 2008). The exception to this is the eye muscles, which become hyper-sensitised leading to increase ocular activity (or rapid eye movement, hence the name) thought to be directly related to the internal visual imagery associated with dreaming (Aserinsky et al., 1985). However, a recent study of 32 participants utilising electroencephalography (EEG) monitoring in a sleep lab, has now found that people actually dream in both REM and NREM sleep. Technology, such as polysomnography (PSG) and EEG have allowed researchers to make fascinating discoveries in the area of sleep research. However, these methods generally employ low numbers of participants due to the individual nature of the data gathering. The requirements of PSG and EEG being facilitated in a sleep laboratory make the use of this technology difficult for certain cohorts or employment sectors.

In situations where normal sleep architecture is altered, circadian misalignment can occur. The term circadian arises from Latin; *circa* meaning ‘about’ (or ‘near’) and *dies* translating to ‘day’ (or 24 hours). In the 1950s, the German biologist Jürgen Aschoff undertook extensive research into the endogenous body clock of humans (Daan and Gwinner, 1998), discovering that an internal body clock existed that operated over a 23-25 hour period. Aschoff coined the term *Zeitgeber* (‘time giver’) for external cues that regulate the circadian rhythm of humans (Aschoff, 1960). As an example, in the early hours of the morning, the brain signals parts of the body to generate heat in preparation for the day ahead. An increase in core body temperature disrupts sleep and promotes waking (Szymusiak, 2005). Whilst the light-dark cycle is the major regulator of sleep, other zeitgebers such as food and drink intake, exercise, and social interactions also affect human circadian rhythms (Quera Salva and Hartley, 2012). These circadian rhythms regulate the autonomic nervous system to control blood pressure, immune response, neural activity and hormonal regulation.

Alterations to the normal sleep-wake cycle, such as employment schedules requiring work at unusual or varied times of the day, results in sleep opportunities that do not fit the biological preference. This inevitably leads to a misalignment of natural circadian patterns which may contribute to altered physiology and impaired cognitive function.

1.2 Poor Sleep and Health

1.2.1 Cognition

Multiple studies have concluded that poor sleep impairs cognition and presents important safety concerns for individuals and society at large (Meijman et al., 1993, Cho, 2001, Marquié et al., 2015). From an Australian perspective, 1011 shift-working adults

(>18years) were randomly selected from an online database as part of a 2016 national study commissioned by the Sleep Health Foundation of Australia (Adams et al., 2017). Participants had previously completed online questionnaires about work arrangements, sleep, fatigue, and health and wellbeing as part of the Australian 2010 Sleep in Adults Survey (Hillman and Lack, 2013). The self-reported data showed that 29% of workers admitted making errors at work in the previous three months due to poor sleep. A further 20% of respondents reported falling asleep whilst driving and 5% reported having a vehicular accident in the past year due to fatigue (Adams et al., 2017). This supports other research which has shown that alterations in the normal sleep–wake cycles lead to fatigue (Courtney et al., 2012) and a deterioration in performance (Nakata et al., 2004, Folkard and Lombardi, 2004). The Australian data derives from shift workers across many and varied industry sectors, however, it is in the medical field where errors can lead to adverse patient outcomes.

Research conducted by Daugherty et al. (1998) showed that medical professionals in the early stages of their careers were more likely to experience sleep disturbance and high levels of fatigue than more experienced colleagues working the same hours. At a time when learning is vital for skill acquisition, acute sleep loss has been shown to reduce hippocampal neurogenesis leading to disruption of short term memory (Vedhara et al., 2000) and impaired cognition (Kim et al., 2007). Samkoff and Jacques (1991) also linked the effects of sleep deprivation and fatigue with medical errors in early career medical residents. Their findings showed that sleep-deprived residents made more errors when sustained vigilance was required for repetitive and routine tasks. Whilst these publications relate to early career medical professionals, no specific research is available that examines sleep disturbance in early career paramedics.

1.2.2 Cardiovascular health

Poor sleep quality and sleep deficit is known to elicit a stress response, activating the hypothalamus-pituitary-adrenal cortex (HPA) axis. This leads to an increased secretion of the glucocorticoid cortisol from the adrenal cortex (Kirschbaum and Hellhammer, 1989). Cortisol increases cardiovascular output, leading to an increased workload on the heart. The increased sympathetic drive also results in an increased mean arterial blood pressure (Kato et al., 2000). Blood pressure is physiologically regulated by several systems in the body. Hormonal control over the renal system regulates blood volume and fluid reabsorption, whilst cardiac output and peripheral vascular resistance fall under autonomic nervous system control via a series of baroreceptors. During healthy sleep, blood pressure is known to dip slightly and is thought to be a homeostatic mechanism (Cortelli et al., 1996, Bursztyn et al., 1994). A study by Lusardi et al. (1999) found that even after half a night of sleep loss, subjects were observed to show increases in systolic blood pressure of around 7% compared to values recorded after a full night's sleep. Strong links have been found between chronic sleep loss and an increased incidence of hypertension, particularly amongst subjects less than 65 years of age (Mullington et al., 2009). Of major concern is research published by Guo et al. (2013) that examined 9,118 retired shift workers from a car making company in China. Researchers found that employees subjected to more than 10 years of irregular working hours were at a higher risk of developing diabetes and hypertension.

Circadian misalignment is also known to increase inflammatory markers identified as risk factors for cardiovascular disease (Cuesta et al., 2016, Morris et al., 2016). Of particular concern, a recent study by Morris et al. (2017) examined nine healthy shift workers (3 males and 6 females) from the health care industry. All participants were non-smokers, drug and medication-free (with the exception of the oral contraceptive pill) and considered to be healthy. In this research, the participants undertook two separate 3-day laboratory-based simulations of day and night work. The simulated day work served as a control against shift work. Results demonstrated an 11% (p <0.0001) increase in 24-h high sensitivity C-reactive protein (hs-CRP), a marker of systemic inflammation (Libby, 2006) and a key feature of atherosclerosis. Therefore, the links between shift work and inflammation identified by Libby (2006) have concerning implications for the development of cardiovascular disease in shift workers including paramedics.

1.2.3 Diabetes and metabolic syndrome

Sleep debt, or chronic sleep deprivation, promotes insulin resistance and increases the risk of diabetes and obesity (Knutson et al., 2007). A literature review conducted by Xi et al. (2014) examined the relationship between short sleep duration and metabolic syndrome, a condition strongly linked to prediabetes and cardiovascular disease (Grundy, 2012). The authors reviewed 12 studies that included 18,720 cases of metabolic syndrome against 70,833 control subjects. Statistical analysis was undertaken to determine a pooled odds ratio (OR) for metabolic syndrome against sleep duration (hours). The review concluded that short sleep duration was associated with a significantly increased risk of developing metabolic syndrome (pooled OR = 1.27 compared to 1.07 for longer sleep duration). Similar results were observed for both men and women, and no publication bias was found by the reviewers. Attempts to identify the specific relationship between poor sleep and diabetes in the laboratory setting has found that sleep restriction (<7 hours) impairs glucose tolerance (Buxton and Marcelli, 2010) and reduces insulin production and sensitivity (Nedeltcheva et al., 2009). Further research is needed to examine if other lifestyle factors contribute to the prevalence of metabolic disorders in individuals with short sleep duration. However, it appears likely that continued exposure to shorter sleep duration increases the risk of metabolic syndrome with an increased risk of the eventual diagnosis of diabetes.

1.2.4 Obesity

Acute sleep loss also has concerns associated with nutrition and diet. A 2012 study allowed 24 healthy adults to live in in a sleep laboratory for 12 days simulating a week of shift work as a means of assessing food choices (Heath et al., 2012). Participants were assigned to either a moderate or severe sleep reduction group, and sleep opportunities were adjusted daily to simulate rotating rosters. Whilst living in the laboratory, participants were offered meals and snack options. Those assigned to the severe sleep loss group showed a significantly higher propensity to snack and also chose sweeter options than those in the moderate sleep loss group.

In recent years, researchers found that alterations in sleep patterns associated with circadian misalignment have a major impact on reducing appetite-supressing hormone leptin (Buxton et al., 2012) and increasing appetite-stimulating hormone ghrelin (Qian et al., 2018). Animal studies have also found that total sleep deprivation leads to a marked increase in appetite and food intake (Everson et al., 1989). Furthermore, Cappuccio et al. (2008) looked specifically at links between obesity and short sleep duration in adults and children. Short sleep was defined as an average of less than ≤5 hours sleep in a 24-hour period or a weighted average of less than 5 hours sleep on weekdays and weekends. A total of 634,511 participants were included in the data analysis, with ages ranging from 2 to 102 years, including both males and females from all over the world. The cross-sectional study identified a consistent risk of obesity amongst children and adults who undertook short duration sleeping. Conversely, data showed a -0.35 unit change in body mass index (BMI) for each increased hour of sleep per day for adults (Cappuccio et al., 2008). Therefore, reasonable links exist between sleep loss and obesity with a further potential risk of diabetes.

1.3 Shift Work

1.3.1 Shift workers

Today many workers find themselves working outside of what traditionally would have been considered normal office hours. These workers complete a schedule where one employee takes over from another to complete the same job, also known as shift work (Knutsson, 2004). The 2012 Census conducted by The Australian Bureau of Statistics (ABS) found that 16% of the Australian workforce (1.6 million employees) indicated shift work was part of their main job (Australian Bureau of Statistics, 2012). Whilst data from Europe and North America reports that 20%-30% of the workforce identified as working hours different from regular daytime work (Alterman et al., 2013, Eurofound, 2015).

Shift work is a necessary component of 24-hour healthcare. In the 2016 Australian Census, the Health Care and Social Assistance industry employed 13% of the work force and was identified as the sector of largest employment in the country (Australian Bureau of Statistics, 2016). Comprising doctors, nurses, aged-care workers, and paramedics amongst others, employment in this industry rose by 16% across the previous 4 years. This correlates with an aging population. In 2016, 15% of Australia's population was aged 65 and over. By 2056 this is forecast to be 22%, or 8.7 million Australians over the age of 65 (Australian Institue of Health and welfare, 2017). As the population continues to age, further demands will be placed on the health care system necessitating an increase in workforce numbers.

1.3.2 Physiological effects of shift work

The World Health Organisation currently lists unhealthy diet, tobacco and alcohol use, and limited physical activity as risk factors for cardiovascular disease and metabolic disorders (World Health Organization, 2011). Although there are many confounding aspects that affect sleep amongst shift workers, there is now a growing body of evidence that suggests that sleep loss associated with shift work should also be added to this list. Of particular concern, night time work and rotating rosters have been as identified as factors in cognitive decline leading to dementia (Marquié et al., 2015), several types of cancer (Schernhammer et al., 2001, Schernhammer et al., 2003, Krstev et al., 1999, Pukkala et al., 2003), and reproductive dysfunction (Knutsson, 2003). Additionally, and in one of the largest studies of its kind, a 2001 Swedish population-based study of 27,485 shift workers found higher levels of obesity and increased triglycerides when compared to daytime workers (Karlsson, 2001).

For shift workers, the need to work at varied times of the day impacts on the normal sleep-wake cycle and may lead to acute sleep loss. American researchers have found that approximately 30% of shift workers report sleeping less than 6 hours per 24-hour period, up from 24% two decades ago (Luckhaupt et al., 2010), and compared to approximately 10% of daytime workers (Sallinen and Kecklund, 2010). Numerous other studies have found that permanent day workers sleep longer than workers on permanent night shift (Akerstedt, 2003, Pilcher et al., 2000). This was highlighted by a review conducted between 1996 and 2008 including a total of 28 articles specifically examining shift work, fatigue and sleep quality (Niu et al., 2011). A key finding of this review was that shift workers who slept during the day averaged up to 4 hours less sleep per day than night-time sleepers. This has led to a concept now widely used in sleep science called ‘sleep debt’ (Van Dongen et al., 2003), and specifically relevant to shift workers is the now commonly accepted ‘shift work sleep disorder' (SWSD) (Drake et al., 2004). SWSD has been identified in approximately 10% of the night and rotating shift work population and is a significant risk factor for behavioural and health-related morbidity. Furthermore, SWSD impacts daily living by leading to excessive sleepiness and chronic feelings of fatigue (Akerstedt and Wright, 2009).

Importantly, increased fatigue is known to reduce the desire to undertake physical exercise (Belza, 1994). However, research findings of physical activity in shift workers is mixed. Pietroiusti et al. (2010) identified that night workers exhibited increased sedentary behaviour twice the level of day time workers, increasing the likelihood of obesity and metabolic syndrome. Conversely, a study of activity, stress and sleep quality in 23 nurses working a rotational roster found that the study population exhibited less sedentary behaviour and more light exercise than 21 non-shift workers at the same medical facility (Roskoden et al., 2017). These results support the National Health and Nutrition Examination Survey conducted in the United States in 2005-2006. This population study examined 1536 adult shift workers who worked either regular day shifts, regular evening or night shifts, or a rotating roster schedule. When Loprinzi (2015) examined the data, the rotating shift schedule produced less sedentary activity and more light-intensity physical activity when compared to regular daytime shift work. As most Australian ambulance services operate on a rotational roster system, further research in the field of paramedicine is warranted.

1.3.3 Examining sleep and activity in shift workers

Research has examined sleep in shift workers across many sectors. One of the largest cohort studies reported in the literature comes from a two-year period from 2008 to 2010, assessing 26,463 retired factory workers in China to gauge the effects of long-term shift work on their sleep (Guo et al., 2013) using the Pittsburgh Sleep Quality Index (PSQI) self-report questionnaire. The PSQI consists of 9 questions, and a range of sub-questions, designed to give a score out of 21; the lower the score, the better the sleep quality. The results showed that workers with up to 10 years of shift work experience were prone to poor sleep quality lasting up to 20 years after shift work ceased. This research, and most of the existing data on sleep disturbance in shift workers (Akerstedt, 2003, Axelsson et al., 2004, Courtney et al., 2012, Frakes and Kelly, 2007a, Haddock et al., 2013, Patterson et al., 2010, Pilcher et al., 1997, Son et al., 2008, Takeyama et al., 2009) relies on subjective measures, such as questionnaires and recall. The use of the PSQI in sleep research is widespread, with several studies validating the tool for subjective scores of sleep quality (Buysse et al., 1989, Backhaus et al., 2002b, Mollayeva et al., 2015). Another sleep-focused study by Backhaus et al. (2002a) compared 45 insomnia sufferers to a control group of 45 healthy people. Primarily as a means validating the specificity of the PSQI in a test-retest situation, insomnia suffers were assessed using PSG with sleep log data against the PSQI questionnaire. Researchers concluded that the use of the PSQI showed a high test-retest validity in primary insomnia patients. The Epworth Sleepiness Scale (ESS) is another subjective measure of sleep. This questionnaire asks respondents to rate from 0-3 how likely they are to fall asleep in eight common daily situations (Buysse et al., 2008). The use of the ESS as a reliable indicator of daytime sleepiness has been questioned by Miletin and Hanly (2003). This review argues that the ESS should include questions pertaining to the likelihood of falling asleep whilst at work, an activity most people perform for extended periods of time each day. It also contends that question eight in the ESS regarding the propensity to fall asleep 'in a car, while stopped for a few minutes in traffic' should be worded to specify sleepiness whilst driving, allowing the respondent to identify as a driver of a car and not a passenger. Others researchers strongly support the use of the ESS for assessing a person's perception of sleepiness (Doneh, 2015), arguing that the ESS is simple to administer whilst providing an accurate indicator of sleepiness in everyday situations.

Supporters and opponents of both the PSQI and ESS agree that the subjective nature of the questionnaires often leads to bias and over-estimation of certain responses (Buysse et al., 2008, Lauderdale et al., 2008). This was evident in one large cohort study finding participants with a PSQI score of >5 underestimated their total sleep time (TST) by 60 minutes on average (Zinkhan and Kantelhardt, 2016).

To gain quantitative data that objectively measures sleep quality, researchers usually employ PSG and EEG. Whist considered gold standard in sleep research since 1968 (Wolpert, 1969, Berry et al., 2012), these techniques are difficult to perform at an employee's workplace and not appropriate for longer periods of data collection. This has driven the need for more portable technology to accurately measure sleep. First discussed in literature in 1974 (Kupfer et al., 1974), an actigraph is a general term used to describe a portable computerised device that measures levels of activity. These devices can either be worn on the waist or hip region of the participant, or more commonly for studies that involve activity and sleep, they can be worn on the wrist (Anderson et al., 2014, da Silva et al., 2014, Sabia et al., 2014). In 2003, a group of researchers from the American Academy for Sleep Medicine (AASM) published practice parameters for the use of actigraphy in the study of sleep (Littner et al., 2003). Their recommendations were formed from a review of 189 published articles utilising actigraphy as an assessment of sleep. Some recommendations from this review were: actigraphy is valid in detecting sleep in healthy individuals; preferred placement of actigraphy on different parts of the body is not well established, although non-dominant wrist is used by most researchers; a minimum of 3 consecutive 24 hour periods of actigraphy is recommended; and concurrent use of sleep log for timing of in-bed and out-of-bed time is recommended (Littner et al., 2003). In addition, the second edition of the International

Classification of Sleep Disorders (ICSD-2) lists actigraphy as a suitable diagnostic tool for longer term assessment of sleep where PSG is impractical (Thorpy, 2012). An update to these 2003 AASM practice parameters was published several years later that further recommended: actigraphy is indicated in the assessment of certain sleep disorders, such as shift work sleep disorder; and, where PSG is not available, actigraphy is a reliable measure of TST (Morgenthaler et al., 2007).

Actigraph technology has also developed quickly over recent times. Modern devices, such as the validated Actigraph GT9X Link (Actigraph, LLC.) (Sasaki et al., 2011, Hanggi et al., 2013, McVeigh et al., 2015, Rosenberger et al., 2016) record continuously at 100 Hz, or 100 measurements per second, and utilise a 3-axis accelerometer to more accurately distinguish movement. Recorded data is then logged as ‘counts’ over a specified time period, called an epoch (van Hees et al., 2015) and can be stored in the internal memory of the device for several months. As a lack of movement is utilised to determine sleep, this premise becomes complicated by minor body movements during sleep, such as those associated with respiratory activity. To overcome this, Cole et al. (1992) undertook a study to distinguish sleep from wakefulness using single axis wrist-worn actigraphy. This research calculated activity counts during four 1-minute epochs followed by two 1-minute epochs (with an overlap period of 10 seconds) in an effort to identify sustained lack of movement as sleep (Zinkhan and Kantelhardt, 2016). Additional work was undertaken in 2010 by Kripke and colleagues to utilise calculated weighted averages over 21 epochs of 30 seconds to further refine sleep from actigraphy data (Kripke et al., 2010). These two investigations led to the development of the Cole-Kripke algorithm used by the ActiLife software (Actigraph, LLC.). This algorithm is specifically designed for adult participants and utilises 1-minute epochs which are considered suitable for assessment of sleep in healthy populations (Littner et al., 2003).

Direct comparison of wrist-worn actigraphy and PSG was conducted by Kushida et al. (2001) and found that actigraphy was rated as excellent in detecting sleep with a sensitivity of 0.92. In a recent study which examined seventeen community dwelling participants (aged 50-75 years), researchers set out to validate specific parameters of sleep data recorded by an actigraph compared to PSG (Full et al., 2018). This research concluded that TST, Sleep Efficiency and Wake after sleep onset (WASO) recorded by the actigraph were not significantly different from those recorded by PSG. Additional studies have also validated actigraphy against PSG (Arora et al., 2013, Blackwell et al., 2008, Pittman et al., 2004), however authors of these papers all agree that the definitive gold standard for sleep assessment is achieved using PSG in a sleep lab. The limitations of these research studies also note that small cohorts of participants were involved with all concluding that further research is required to support that validation of actigraphy against PSG.

Good sleep quality has been shown to be vital for overall health and well-being, whereas sleep quantity appears to have little correlation (Pilcher et al., 1997). Sleep duration is the number of minutes scored as ‘asleep’ in an episode of sleeping, based on lack of movement, or movement within specific parameters, detected by the actigraph. This commences when the algorithm determines the subject has first gone to sleep, called sleep onset. The period of time from going to bed to the first minute of sleep is called sleep latency. Short sleep latency has been shown to correspond with subjective responses of good sleep quality (Riedel and Lichstein, 1998). To obtain sleep latency, actigraph data is often correlated against sleep logs or a sleep diary. An epidemiologic study in 2006 reported significant overestimation of total sleep noted on sleep logs when compared directly to actigraphy (Lauderdale et al., 2006). Conversely, insomnia suffers commonly underestimate total sleep time when recording in a sleep diary (Vallieres and Morin, 2003), making the use of objective data from the actigraph vital.

WASO is also determined by the software algorithm and is a tally of the total number of minutes a subject is awake after sleep onset occurred. Sleep Efficiency is calculated as a percentage of time spent ‘asleep’ from the time spent in bed. Participants also manually record their ‘In-bed’ and ‘Out of Bed’ times and this gives the total in bed time. Sleep duration, excluding sleep latency or WASO, as a percentage of the total in-bed time yields Sleep Efficiency. Literature suggests that a Sleep Efficiency of 87% or more correlates with a subjective response of a good sleep whilst 57% or lower elicits a subjective response of poor sleep (Akerstedt et al., 1994). The Number of Awakenings (NoA) recorded each night also gives an indication of sleep quality. Almost every transition between phases of sleep, or sleep to wake, is associated with arm movements or rolling over in bed (Zinkhan and Kantelhardt, 2016). Whilst this is normal, higher NoA have been correlated with subjective responses of poor sleep and general poor health (Pilcher et al., 1997). Therefore, the metrics of NoA, WASO and Sleep Efficiency can be utilised as slightly different indicators of restless sleep (Wilson et al., 2011).

The non-invasive nature of actigraphy, allowing participants to sleep in their own beds, coupled with the cost effectiveness and previously mentioned validation of the technology, indicate that actigraphy is a suitable objective measure of sleep quality in shift workers such as paramedics. The added benefit of activity tracking also allows investigation of sedentary behaviour and exercise amongst the study population.

1.4 Paramedics

1.4.1 The paramedic workforce

Paramedics are often the first point of contact for a person experiencing a medical emergency, traumatic event or social crisis, and thus play an integral role in the health care system. A Council of Ambulance Authorities (CAA) annual report in 2013 stated that there were 15,220 effective full-time ambulance service employees in Australia in the previous 12 months, with 82% in an operational capacity (Council of Ambulance Authorities, 2013). Of these, 16% were student or graduate paramedics and 22% of total operational paramedics were aged under 30 years. 21% of paramedics in Australia were over the age of 50 and annual attrition was quoted as 4.3%, but varied from 5.5% in New South Wales to only 1.4% in South Australia.

Demand for pre-hospital emergency care and transport requires a 24-hour workforce, historically relying on rotating rosters of two 10-hour day shifts followed by two 14-hour night shifts, and then four rostered days off work. This standard platform, called 10/14 rostering, was first introduced to Australian fire services in 1975 (FBEU, 2016) and was adopted shortly after by most Australian ambulance services. This rostering structure allowed for the uneven distribution of call outs seen around this time, with most emergency calls being received during the daylight hours. In the case of busier nights, traditionally the weekends, emergency responders were only exposed to these on a rotational basis with the quieter mid-week nights allowing for extended periods of rest (Bloomfield et al., 2005). Researchers looking specifically at rotational rosters have found that workers overcome a sleep loss during the shift work component by sleeping longer on non-work days and at the conclusion of night duty (Alward and Monk, 1990, Escriba et al., 1992). Of concern, however, are findings that staff working a rotating roster schedule have a higher incidence of hypertension and diabetes than any other shift work schedule, including permanent night shift workers (Gan et al., 2015, Manohar et al., 2017).

Most Australian ambulance services are now introducing a 12-hour afternoon shift in place of the first night shift, to alleviate the fatigue of consecutive 14-hour night shifts. This move is in line with nursing research by Rogers et al. (2004) which found that shift lengths over 12.5 hours were associated with a threefold increased risk of medical errors. Research by Tucker et al. (2017) also supports this, citing that doctors who worked shifts more than 12 hours in duration were five times more likely to report fatigue regardless of the total weekly hours worked. Additional evidence over the past two decades linking longer shift durations and negative patient outcomes (Lockley et al., 2007, Trinkoff et al., 2007, Rogers et al., 2004) has driven a change in health care to adopt shorter shifts to reduce fatigue.

Whilst most research in the healthcare field examines hospital-based staff, very little research exists that specifically looks at emergency medical first responders. Sofianopoulos et al. (2012) conducted an electronic database literature review of articles relating to fatigue, work stress and sleep disturbance in the prehospital setting. Of this review, only one paper examined fatigue and sleep quality for Australian paramedics, utilising a subjective questionnaire (Mahony, 2001). Eight other papers explored fatigue in emergency medical responders from other countries, whilst no research was found to study fatigue in new recruits (Aasa et al., 2005, Alexander and Klein, 2001, Goldstein et al., 1992, Frakes and Kelly, 2007b, Okada et al., 2005, Roth and Moore, 2009, Takeyama et al., 2009, Young and Cooper, 1997). The lack of available literature highlights a clear gap in quantitative research of paramedics who play such an important role in the Australian healthcare system.

1.4.2 Paramedic workload and stress

An Auditor-General's report in 2010 examined the access to ambulance services in Victoria from 2006-10 (Victorian Auditor-General, 2010), including utilisation rates. Utilisation rates encompass the proportion of time an ambulance is assigned to a case, being both travel time to the case, treatment of the patient and transport to a hospital. The time paramedics are not assigned to a case is referred to as 'down' time. Theoretically, this time should allow for rest and recovery, but also includes time paramedics spend returning from a case back to the ambulance station. In the metropolitan area of greater Melbourne, a consistent utilisation rate of approximately 49% was identified for the years 2006-10. In rural regions, utilisation rates varied from a low of 4.3% in Apollo Bay to a high of 59.2% in Bendigo, with data analysed from 2009-10. The major population centres of Ballarat, Morwell and Geelong all averaged higher utilisation rates than metropolitan Melbourne (Victorian Auditor-General, 2010). Follow-up data beyond 2010 is not currently available.

The increasing demand for ambulance resources correlates with reported data of increased stress in paramedics. Joyce et al. (2009) noted that a survey conducted by the ambulance employees' union reported that 98% of paramedic respondents had considered themselves to be fatigued in the previous 12 months, with 73% stating higher workloads as the main causative factor. The same article continues on to state that 87% of respondents 'reported that fatigue had affected their judgement at work' (pg. 533), whilst fatigue has been shown to affect concentration, judgement and work performance (Chinawa et al., 2014). Therefore, fatigue associated with poor sleep, has the potential to lead to adverse patient outcomes in the pre-hospital environment.

Australian researchers have also found that workers who get an inadequate amount of sleep are more likely to take sick leave than those who are well rested (Reynolds et al., 2017), adding additional strain to ambulance services that are already dealing with increasing demand. Motohashi and Takano (1993) undertook a study of Japanese ambulance staff who worked a full 24-hour roster followed by one or two days off and found that these staff had permanent changes to the characteristics of their circadian rhythm. Another study (Takeyama et al., 2009) investigated the same cohort of emergency responders and incorporated the provision of nap time for staff working a 24-hour roster. Compulsory naps were implemented for either 5 hours during the afternoon or 6 hours over night. Paramedics reported that the compulsory down time allowed them to improve their physiological function and alleviate subjective fatigue, with improved reaction times recorded at the conclusion of the 24-hour shift. Additionally, recent research has identified that on-shift napping during a night shift reduces circadian misalignment and may protect against hypertension and weight gain (Rotenberg et al., 2016, Silva-Costa et al., 2017).

From an Australian perspective, Sofianopoulos et al. (2011) examined sleep as part of a broad context survey of 60 Australian paramedics. This research utilised the PSQI and the ESS to conclude that over two-thirds (68%) of respondents reported poor sleep quality in the previous 6 months. The research supported previous results by Courtney et al. (2012) utilising the same scoring tools to establish that 72% of paramedics in their study were identified as poor sleepers. Of note in the Sofianopoulos et al. (2011) pilot, only 9 (15%) of the 60 paramedics surveyed were paramedics of less than 5 years' experience, with no indication as to how many were new recruits. Since 2011, no further research has been published examining sleep and fatigue issues of Australian paramedics.

1.4.3 Early career paramedics.

In Australia, each ambulance service employs graduate paramedics who have completed a bachelor's degree at a recognised university. The rise in popularity of an ambulance career has also increased over the past 15 years (Hou et al., 2013), coinciding with a shift from ambulance service-run training colleges to an undergraduate university degree for paramedicine. The CAA, the regulatory body that accredits university paramedic courses in Australia, estimated that in 2014 there were 6,367 students enrolled in a paramedic program in Australia (Council of Ambulance Authorities, 2013). Of these, an estimated 75% will go on to employment with an Australian ambulance service (Waxman and Williams, 2015), yet no available research examines how these new graduates adapt to shift work in the ambulance sector.

In their 2016-2017 annual report, Ambulance Victoria (AV) noted an unprecedented demand for ambulance response in Victoria. During this time 847,924 cases were attended, an increase of 3.6 percent since 2013 (Ambulance Victoria, 2017). Comparatively in other states and territories, Ambulance Tasmania responded to 78,743 cases in the 2014-15 financial year; an increase of 8.6% from the number of responses in 2011-12 (Department of Health and Human Services, 2015). In South Australia, the Ambulance Service reported an increase of 5.7% in emergency responses in 2016-2017 compared to the previous year (SA Ambulance Service Inc, 2017), and in Queensland a 4.3% increase in responses was recorded for the 2016-2017 year (Queensland Department of Health, 2017). The authors of these reports highlight the aging population and the increase in the number of chronic medical conditions as reasons for the increased demand for ambulance services.

In order to meet growing demand, the Victorian paramedic workforce increased by approximately 10% in 2014 with a total of 291 new graduate paramedics employed; intakes were similar in 2014-2015 and 2015-2016 at 234 and 241 new graduates (Ambulance Victoria, 2017). The 2016-2017 financial year coincided with a state government promise to bolster paramedic numbers, resulting in a huge employment of 439 new graduates (Ambulance Victoria, 2017). In just four years, over 1200 inexperienced paramedics commenced shift work in Victoria. In the 2013 CAA annual report, Victoria had the second youngest paramedic workforce, with 26% being under the age of 30, slightly behind the Northern Territory at 28% (Council of Ambulance Authorities, 2013). Given the high number of graduates employed in Victoria since 2014, this percentage is likely to have surpassed all other states and territories.

Early career is a time when graduates should be undertaking new skills, honing the theoretical knowledge from their university education and applying it in practice. Research from the nursing field indicates that the first five months of employment is an intense period of adaption often involving self-doubt, anxiety and a lack of confidence (Ortiz, 2016) often leading to emotional exhaustion (West et al., 2007). Additional nursing research identifies the 12-month period as a landmark for a stable level of confidence (Duchscher, 2012), but no research is available that examines this initial period of paramedic practice. Adding in the aforementioned work environment in which changes between day and night shifts are routine, the issues of sleep, health and activity of new paramedics need to be explored in detail. Therefore, this project is vital as it seeks to investigate two main issues that affect the graduate paramedic and their work.

1.5 Aims and Hypotheses

Firstly, this study aims to determine if the quality and quantity of sleep is altered when undertaking the initial five months of rotational shift work, as compared to the month of non-shift work immediately prior. This will be achieved by assessing total sleep hours across a 25-day period at Month 0 (Baseline), Month 1 and Month 5. In additional, Sleep Duration will be examined on shift work days and non-working days and compared to Baseline data. Sleep quality, determined by Sleep Efficiency, NoA and WASO, will also be examined across the Month 1 and Month 5 to determine if alterations from Baseline are presenting. It is hypothesised that the nature of rotating shift work disrupts normal sleep-wake cycles leading to diminished sleep quality and quantity in early career paramedics. Poor sleep quality is further linked to increased lethargy and fatigue. This will reflect in reduced activity and increased sedentary time amongst graduate paramedics as they undertake shift work.

Secondly, this study aims to investigate if early risk factors of cardiovascular disease and metabolic disorders manifest in the first five months of rotational shift work. This will be achieved by assessing metrics of health and wellbeing including height, weight, waist circumference, resting heart rate, blood pressure, fasting blood glucose, body composition, and aerobic fitness (step test) at the commencement of the Baseline period, at the conclusion of shift work Month 1, and pre- and post- shift work Month 5. It is hypothesised that early risk factors associated with cardiometabolic disease states will present during the first five months of shift work.

2.0 Methodology

2.1 Ethics

Ethical approval was granted by the Tasmanian Health and Medical Human Research Ethics Committee on 11th September 2015 (reference number H0015110). The Research Committee of Ambulance Victoria (AV) approved the project on the 30th September 2015 (reference number R15-008).

2.2 Participant recruitment

Graduate students starting their employment with AV were targeted for recruitment in to this study. Promotion of the study included presentations to undergraduate Bachelor of Paramedicine students at the Australian Catholic University, posters at other Universities throughout Victoria that offer a recognised paramedicine degree, and information on the University of Tasmania Research Participants webpage. In addition, all graduate paramedics employed by AV received an invitation to participate in the study with their offer of employment. Participants registered their interest via the University of Tasmania Research Participation Form (http://www.utas.edu.au/health/research/participate/stress-in-graduate-ambulance-paramedics/information-page) and were then contacted by phone to discuss the research project and their eligibility for the study was assessed.

2.3 Exclusion criteria

Exclusion criteria included diagnosed sleep disorders and those taking medication which affects the central nervous system or sleep regulation (e.g. medications for epilepsy, anxiety, mood disorders, sleeping tablets such as Stilnox, benzodiazepines, or melatonin).

Potential participants were advised of these exclusion criteria via the University of Tasmania Research Participation Form. Additionally, participants were excluded from the study if they had any chronic health conditions, such as cardiovascular or metabolic disease, assessed via the participant consent form.

2.4 Participants

28 participants (13 male and 15 female) completed the full study protocol. A further five participants completed part of the protocol but withdrew for various reasons. One participant withdrew early from the project and reported a mild dermatitis reaction from wearing the actigraph. No other adverse effects were reported. Two participants withdrew prior to the Month 5 assessment period. Two additional participants were withdrawn at the conclusion of Baseline due to large gaps of missing sleep and activity data. One did not wear the actigraph for a week during this assessment phase and the second consistently failed to wear the device whilst sleeping, therefore complete data could not be obtained for both participants. A final participant was withdrawn at the conclusion of Month 5 as a result of only wearing the actigraph whilst sleeping, therefore accurate activity data could not be obtained rendering previous data also unusable.

Only graduates employed by AV to work in metropolitan Melbourne or the busy regional centres of Geelong and Bendigo were accepted for this research. The locations chosen have a similar paramedic utilisation rate, therefore allowing for consistency in workload exposure, similar levels of incidental overtime and similar amounts of on-shift rest time amongst participants. Other graduates from regional areas with lower utilisation rates were not used, due to the likelihood of increased rest time on night duty leading to inconsistent sleep data.

2.5 Study protocol

Graduate paramedics were assessed prior to commencement of shift work (Baseline), and in the first and fifth months of their operational rotations (Figure 2.1). During these assessment phases, participants were assessed for a range of outcomes related to general health and sleep quality (see below for details).

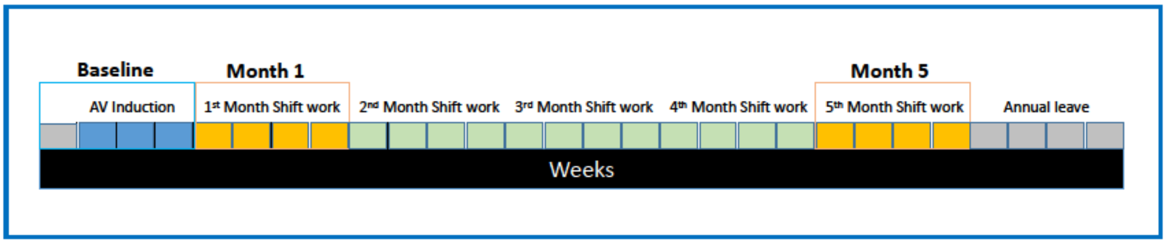

Figure 2.1: Study protocol spanning the first six months of graduate employment with AV. Blue indicates induction weeks; Grey indicates non-ambulance working weeks; Orange indicates weeks of shift work when the participant is being assessed, and Green indicates shift work where the participant is not being assessed as part of the study protocol.

Paramedics in Victoria work across a four-week (28-day) roster block, normally centred on the standard 10/14 rostering (two consecutive 10-hour day shifts followed by two consecutive 14-hour night shifts). As part of this rostering pattern of four days on and four days off, paramedics may finish any particular roster block on four rest days. To accommodate this, the data collection period for each assessment phase was set at 25 days.

2.5.1 Familiarisation

Prior to commencement of the protocol, participants attended a familiarisation session (see 2.7.3 Physical Testing below) at a testing centre located at Australian Catholic University in Fitzroy, Victoria. The full study protocol (Figure 2.2) was explained to participants, with the opportunity to ask questions before informed consent was obtained. Training was provided on the use of the actigraph watches and charging procedure. Individualised testing schedules were provided to each participant along with copies of the sleep log form. Participants were instructed to record 'in-bed' time on their sleep log form as the time they intended to fall asleep. Each participant was requested to be accurate to the minute to allow for sleep latency to be established from the actigraph.

2.5.2 Baseline

AV's graduate induction program is structured around three weeks of classroom activities and driving assessments. The induction program, and the days immediately beforehand totalling a 25-day period, form the baseline assessment period for the participants. This assessment period provides baseline data with no shift work and serves as a comparison to the further assessment periods undertaken during rotational shift work.

2.5.3 Month 1

Immediately following the induction process, graduates commence as operational paramedics undertaking rotational shift work. Depending on their allocated roster, this occurs as early as the Monday following the conclusion of induction. This first month of shift work, referred to as Month 1, is used to identify acute changes to sleep quality or quantity, activity levels or general health and wellbeing.

2.5.4 Month 5

The fifth month of shift work is referred to as Month 5, is used to assess chronic changes to sleep quality or quantity, activity levels or general health and wellbeing.

2.6 Sleep and activity assessment

Participants wore the Actigraph GT9X Link (Actigraph, LLC.) device to collect sleep and activity data continuously across each 25-day assessment period. Measures relating to the percentage of time spent sedentary or engaged in moderate to vigorous physical activity (MVPA) and the number of steps per day were obtained. Sleep data was also assessed during rostered days off / non-work days (RDOs) during Month 1 and Month 5. Specific sleep data was also obtained for the sleep period immediately after night shift work and for the sleep prior to commencing each four-day block of shift work.

The Actilife software, utilising the Cole-Kripke algorithm, provided an assessment of sleep quantity and sleep quality. Participants manually record their 'in-bed' and 'out of bed' times on their sleep log to establish total in bed time. From this, *Sleep Duration* - the number of hours/minutes scored as 'asleep' - was established for each *Sleep Episode*. *Sleep Efficiency* was calculated as a percentage of time spent 'asleep' from the time spent in bed. The *Number of Awakenings (NoA)* and *Wake After Sleep Onset (WASO)* for each sleep period were derived, as an indication of sleep quality. *Total sleep time (TST)* was recorded in hours and minutes as a cumulative tally of total sleep from all sleep episodes over the 25-day period of each assessment inclusive of naps.

2.7 Health and wellbeing

A health and wellbeing assessment was performed at Baseline, at the conclusion of Month 1, prior to the beginning of Month 5 of operational shift work, and at the conclusion of Month 5 (see figure 2.2). During this assessment participants completed questionnaires relating to stress and sleep, and basic physical testing to assess overall health.

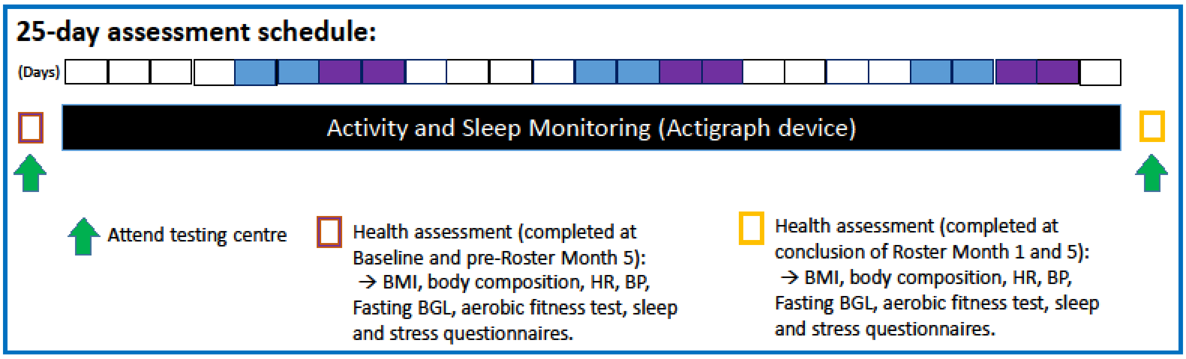

Figure 2.2: Study protocol for each assessment period during the first six months of shift work. Blue squares indicate day shift and purple squares indicate night shift of a typical roster rotation during Month 1 and Month 5 (days vary depending on individual roster line). No shift work occurs during Baseline assessment period.

2.7.1 Stress questionnaire

Participants completed a stress questionnaire (International Stress Management Association UK) consisting of 25 yes/no questions relating to the participant's level of perceived stress (see Appendix 1) (Van Staden, 2013). A numerical score was obtained, with 4 points or less indicating the participant was least likely to suffer from stress-related illness. A score between 5 and 13 points suggests that the person was more likely to experience stress-related ill health – either mental, physical or both – whilst a score over 14 points was suggestive the person was highly likely to experience stress & stress-related illness (Kaur and Kumar, 2017).

2.7.2 Sleep quality questionnaire

Participants completed the Pittsburgh Sleep Quality Index (PSQI) questionnaire (Appendix 2), a widely used tool in sleep research that is commonly accepted as a valid measure of subjective sleep quality (Buysse et al., 1991, Backhaus et al., 2002b, Mollayeva et al., 2015). The questionnaire consists of nine questions, and sub-questions, to give a score out of 21; the lower the score, the better the sleep quality (Buysse et al., 1989). Questions cover several key areas: subjective sleep quality and efficiency, sleep duration, sleep disturbances and sleep latency. Additional questions also relate to the use of sleep medication and daytime dysfunction (Ong et al., 2011).

2.7.3 Physical testing

At the testing centre, participants had their blood pressure (BP) auscultated using a calibrated sphygmomanometer (Heine Optoechnik). BP was determined from two readings 10 minutes apart in a seated position with the average recorded. Resting heart rate (HR), post 10 minutes of seated inactivity, was recorded using a Polar Electro F32 HR monitor and T31-coded chest band. Fasting blood glucose (BG) levels were assessed via a finger prick blood sample and analysed using a FreeStyle Optium glucometer (Abbott Group). Due to the requirement of a 6-hour fasting BG level, physical testing occurred in the morning between 0630 and 0930 for all participants throughout the study.

Each participant was then asked to stand barefoot with their head erect whilst their height was measured to the nearest 0.1cm using a stadiometer. Weight, in light clothing, was recorded to the nearest 0.1kg via digital scales (A&D Company), and waist circumference was also measured between the navel and costal margin (to the nearest 0.1cm). Participants performed an aerobic fitness test (3min step test) routinely undertaken as part of the applicant testing for Ambulance Victoria, South Australian Ambulance Service, and New South Wales Ambulance Service. This test involved stepping onto a 30cm step in an "up, up, down, down" motion for 3 minutes, in time to a metronome set at 96bpm, i.e. 24 steps per minute. The participant's HR was monitored throughout the procedure via a HR monitor. At exactly three minutes, the participant was asked to sit in a chair and their HR was recorded continuously for one minute. This represented their recovery HR and allowed an estimation of the maximum rate of oxygen consumption used by body tissues during exercise, or the Volume and Oxygen maximum (VO_2max). The VO_2max is expressed as a relative rate of oxygen consumption in millilitres of oxygen use per kilogram of body weight per minute. This figure is calculated using standardised formulas for men (111.33-[0.42 x recovery HR/min]) and for women (65.81 – [0.1847 x recovery HR/min]) (McArdle, 2000). The estimated VO_2max for an average male is 35-40 mL/kg/min and for women is 27-31 mL/kg/min, but this number increases with training and declines with age (Hawkins and Wiswell, 2003).

2.8 Data handling

High resolution accelerometer data recorded at 100Hz for 28 participants created almost one terabyte of data. This data was stored locally on a secure password-protected hard drive and backed up to a secure server off-site.

2.9 Statistical analysis

Statistical analysis was completed using SPSS version 24 (SPSS Inc; Chicago, IL, USA) and GraphPad Prism version 5.0 (GraphPad Software, San Diego, CA, USA). All data were reported as means ± standard deviation, and significance was determined as $p < 0.05$. Repeated measure analysis of variance (ANOVA) was used for statistical analysis of three sets of sleep and activity data (across work and non-work days), four sets of data for health, and subjective responses for sleep and stress questionnaires. The distribution of the data (by histogram) and equality of variance were assessed visually to ensure the data satisfied the assumptions of the ANOVA. Sphericity assumptions were met for all data, with the exception of PSQI questionnaire which showed evidence of a non-normal distribution. In order to satisfy the assumptions of the ANOVA, the data for the PSQI were log-transformed and the analysis was re-run.

Sleep data for RDOs was obtained for clear non-work days and excluded sleep immediately after finishing a night duty. Individual sleep periods following night shift were compared, as were all RDOs and specifically the final RDO. Where continuously recorded data exceeded 25 days, the end days were omitted. To counteract possible variations of self-recorded sleep, individual sleep logs were correlated to actigraphy data. This was able to identify log entry errors, such as confusion around AM and PM or if the incorrect day was noted by the participant for 'in-bed' time starting after completing a night shift.

3.0 Results

A total of 28 participants completed the full study protocol. Table 3.1 outlines the subject demographics at the commencement of the study. There were no statistically significant differences in sleep or activity metrics between male and female subjects, therefore combined data has been presented throughout this report.

Table 3.1:

Demographic data for graduate paramedics at the commencement of the study protocol.

	F=15	**M=13**	**Combined (n=28)**
Item	**Baseline**	**Baseline**	**Baseline**
AGE	25.6 ± 4.0	25.5 ± 5.2	25.5 ± 4.5
HEIGHT	168.7 ± 5.4	177.9 ± 7.0	172.9 ± 7.7
WEIGHT	71.2 ± 14.2	80.2 ± 13.6	75.4 ± 14.3
WAIST CIRCUMFERENCE	71.0 ± 11.2	79.3 ± 11.3	74.9 ± 11.8
FASTING BG	5.0 ± 0.7	5.1 ± 0.5	5.0 ± 0.6
RESTING HR	83.7 ± 10.9	79.5 ± 10.5	81.8 ± 10.7
SYSTOLIC BP	116.8 ± 8.6	127.9 ± 8.2	122.0 ± 10.0
DIASTOLIC BP	82.5 ± 4.9	89.6 ± 10.1	85.8 ± 8.4
VO_2max	40.1 ± 3.8	56.3 ± 7.0	47.6 ± 9.9

Data recorded as: Age (yrs), Height (cm), Weight (kg), Waist Circumference (cm), Fasting BG (Mmol/L), Resting HR (bpm), Systolic and Diastolic BP (mmHg) and VO_2max (ml/kg/min). Data represented mean ± SD.

3.1.1 Total sleep time (TST) and sleep episodes

Total sleep time was measured across the 25-day assessment period and the mean data for each assessment period is presented in Figure 3.1A. A significant (p =0.015) increase in total sleep duration was observed from Baseline to Month 1, but no significant change was found between Baseline and Month 5 (p =0.054). Figure 3.1B showed the number of sleep episodes across measured across each 25-day assessment period. A significant increase in the number of sleep episodes was recorded during shift work (Month 1 p <0.005; Month 5 p <0.005) compared to those recorded during the Baseline period.

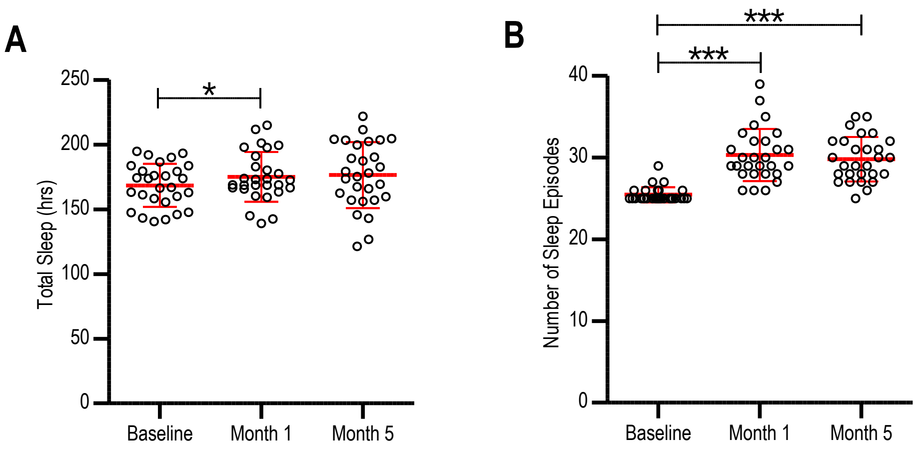

Figure 3.1: (A) 25-day mean TST and (B) 25-day mean number of Sleep Episodes for Baseline (non-shift work), Month 1 (1st month of rotational shift work) and Month 5 (5th month of rotational shift work). * indicating p <0.05 and *** indicating p <0.005. TST measured using Actigraph GT9X Link monitoring devices and referenced against manual sleep episode log entries for each participant. Data presented as mean ± SD, n = 28. Significance determined using one-way ANOVA.

3.1.2 Sleep efficiency

The 25-day mean Sleep Efficiency recorded during Month 1 and Month 5 of shift work did not differ significantly (p =0.17) from the Baseline assessment (Figure 3.2A). This was consistent with results seen during RDOs (p =0.43), and immediately after night duty (p =0.72), and on the last night of RDOs (p =0.77), as shown in 3.3B, C and D respectively.

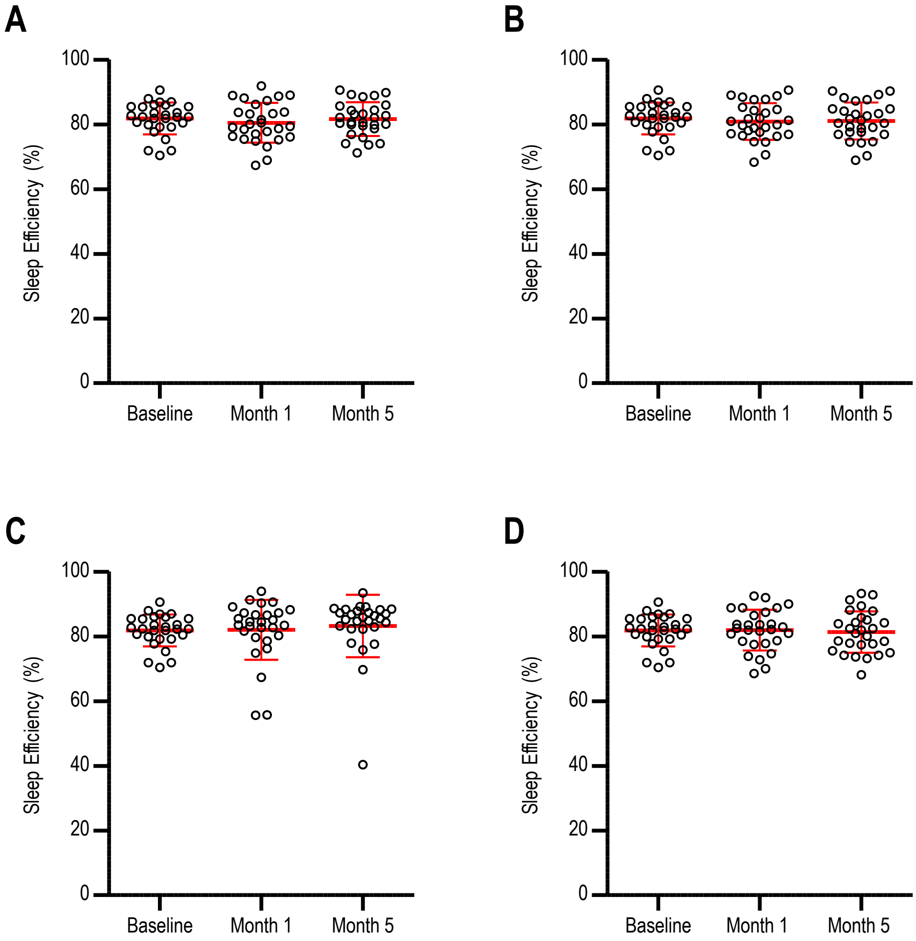

Figure 3.2: (A) 25-day mean Sleep Efficiency for Baseline (non-shift work), Month 1 (1st month of rotational shift work) and Month 5 (5th month of rotational shift work). (B) Baseline and Sleep Efficiency from all non-shift work days (Rostered days off – RDOs) in Month 1 and Month 5. (C) Baseline and Sleep Efficiency from all sleep episodes immediately following night duty in Month 1 and Month 5. (D) Baseline and Sleep Efficiency from all sleep episodes on final RDO before rostered shift work day in Month 1 and Month 5. Sleep Efficiency was calculated as a percentage of time spent 'asleep' from the time spent in bed, measured using Actigraph GT9X Link monitoring devices and referenced against manual sleep log entries for each participant. Data presented as mean ± SD, n = 28. Significance determined using one-way ANOVA.

3.1.3 Sleep duration

A significant (p <0.005) reduction in Sleep Duration was recorded during the first month of shift work as compared to Baseline (Figure 3.3A). While Month 5 of shift work saw the average Sleep Duration increase from Month 1, this was still significantly (p <0.01) less than Baseline. Sleep Duration during RDOs in Month 1 and Month 5, did not differ significantly from Baseline (Figure 3.3B). Sleep Duration immediately after night duty however is significantly (*p* <0.0001) lower compared to Baseline as shown in Figure 3.3C. Figure 3.3D showed a significant reduction in the sleep duration on the third RDO for both Month 1 and Month 5 compared to the Baseline 25-day mean.

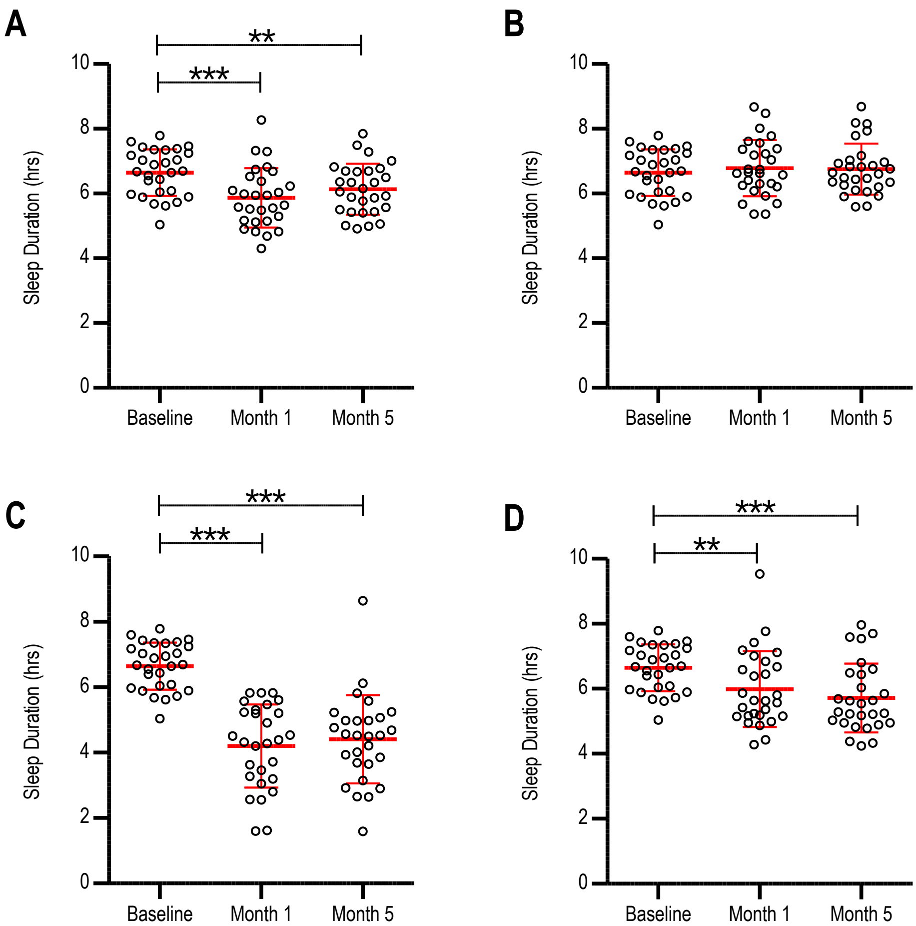

Figure 3.3: (A) The 25-day mean Sleep Duration recorded for Baseline (non-shift work), Month 1 (1st month of rotational shift work) and Month 5 (5th month of rotational shift work) (**indicating p <0.01 and *** indicating p <0.005). (B) Baseline and Sleep Duration from all non-shift work days (Rostered days off – RDOs) in Month 1 and Month 5. (C) Baseline Sleep Duration and Sleep Duration from all sleep episodes immediately following night duty in Month 1 and Month 5 (*** indicating p <0.005). (D) Baseline and Sleep Duration from all sleep episodes on final RDO before rostered shift work day in Month 1 and Month 5 (*** indicating p <0.005 and **indicating p <0.01). The hours of sleep were recorded using Actigraph GT9X Link monitoring devices and referenced against manual sleep episode log entries for each participant. Data presented as mean ± SD, n = 28. Significance determined using one-way ANOVA.

3.1.4 Wake after sleep onset (WASO) as a percentage of sleep duration

WASO, recorded as minutes of waking after sleep onset, is reported by the actigraph software as a simple duration, which was converted to a percentage of time spent awake across each sleep episode. The 25-day mean WASO percentage recorded during Month 1 and Month 5 of shift work did not differ significantly (*p* =0.92) from those recorded at Baseline (Figure 3.4A). This was consistent with results seen during RDOs (*p* =0.29), and immediately after night duty (*p* =0.37), and on the last night of RDOs (*p* =0.71) as shown in Figure 3.4B, C and D respectively.

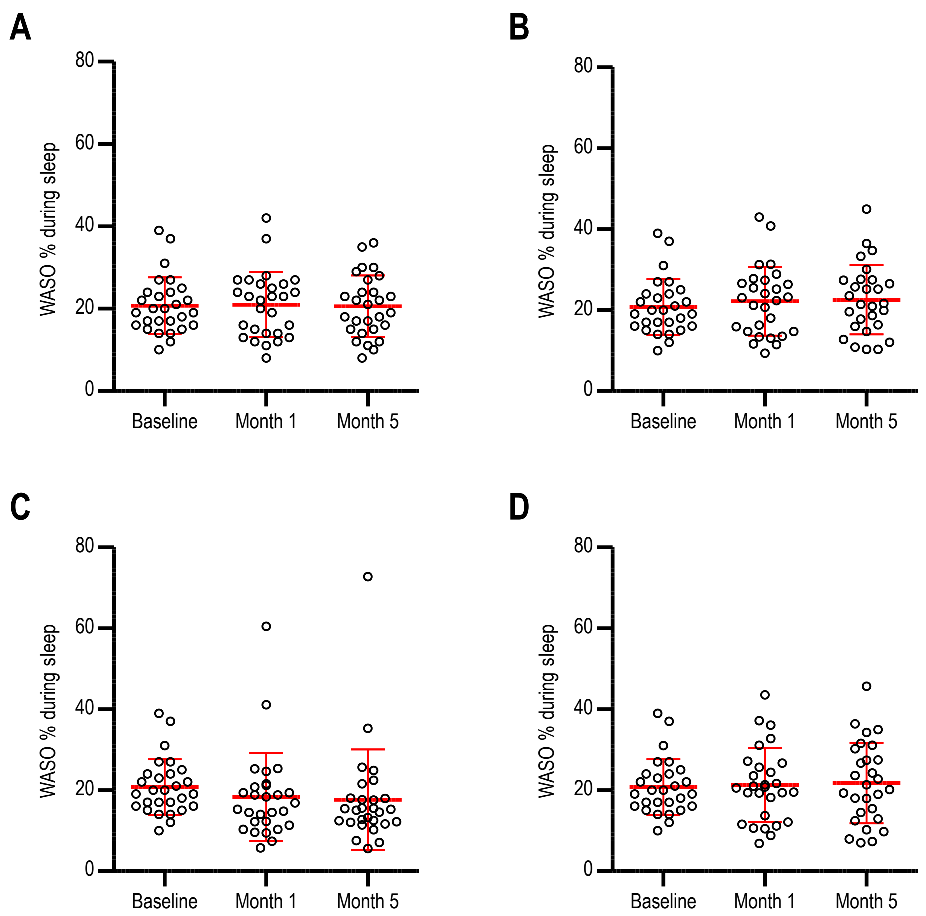

Figure 3.4: (A) The percentage of time spent awake during the sleep period for 25-day mean data for Baseline (non-shift work), Month 1 (1st month of rotational shift work) and Month 5 (5th month of rotational shift work). (B) The percentage of time spent awake during the sleep period during Baseline and all non-shift work days (Rostered days off – RDOs) in Month 1 and Month 5. (C) The percentage of time spent WASO during Baseline and from all sleep episodes immediately following night duty in Month 1 and Month 5. (D) The percentage of

time spent awake during the sleep period during Baseline and from all sleep episodes on final RDO before rostered shift work day in Month 1 and Month 5. The hours of sleep were recorded using Actigraph GT9X Link monitoring devices and referenced against manual sleep episode log entries for each participant. Data presented as mean ± SD, n = 28.

3.1.5 Number of awakenings (NoA) per hour of sleep duration

The 25-day mean NoA per hour recorded during Month 1 and Month 5 of shift work did not differ significantly (p =0.11) from those recorded at Baseline (Figure 3.5A). This was consistent with the rate during RDOs (p =0.93) and the last night of RDOs (p =0.68) as shown in Figure 3.5B and D respectively. The NoA per hour recorded for the sleep immediately after night duty was significantly lower for both Month 1 (p <0.005) and Month 5 (p <0.001) when compared to the Baseline 25-day mean (Figure 3.5C).

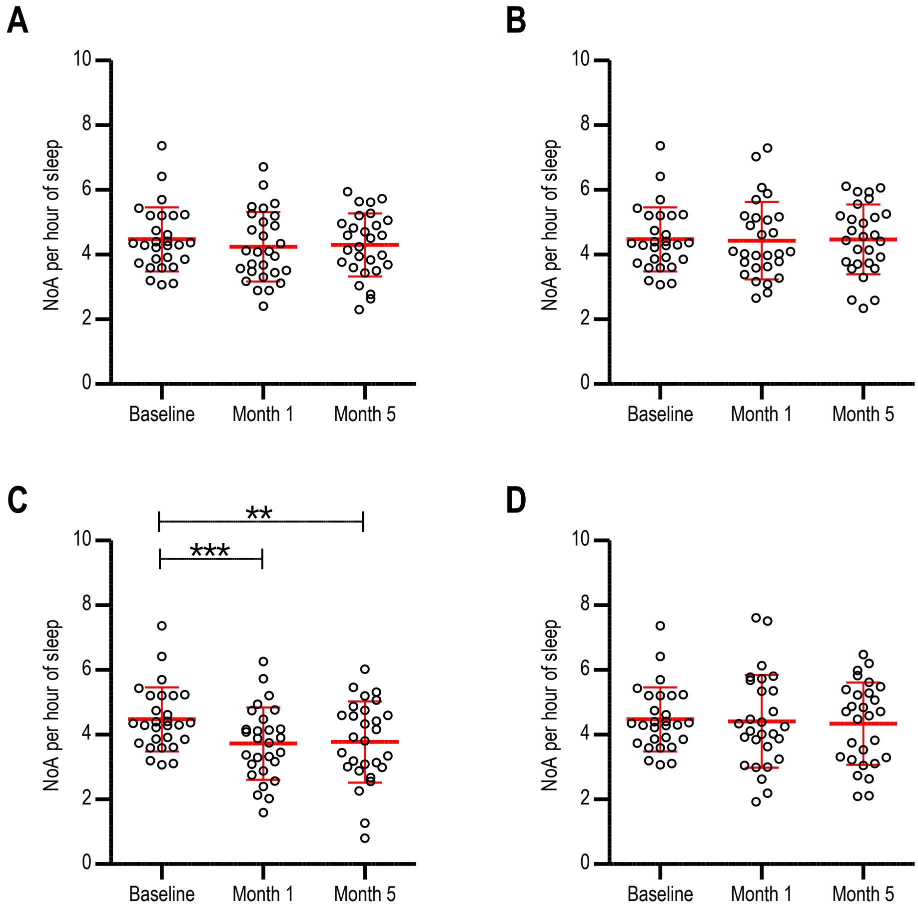

Figure 3.5: (A) NoA per hour for 25-day mean data for Baseline (non-shift work), Month 1 (1st month of rotational shift work) and Month 5 (5th month of rotational shift work). (B) NoA per hour during Baseline and all non-shift work days (Rostered days off – RDOs) in Month 1 and Month 5. (C) NoA per hour during Baseline and from all sleep episodes immediately following night duty in Month 1 and Month 5 (**indicating p <0.01 and *** indicating p <0.005). (D) NoA per hour during Baseline and from all sleep episodes on final RDO before rostered shift work day in Month 1 and Month 5. The hours of sleep were recorded using Actigraph GT9X Link monitoring devices and referenced against manual sleep episode log entries for each participant. Data presented as mean ± SD, n = 28. Significance determined using one-way ANOVA.

3.1.6 Pittsburgh sleep quality index (PSQI)

Subjective sleep quality scores obtained via the PSQI differed significantly (p <0.0001) between assessment periods as shown in Figure 3.6. Scores obtained at the conclusion of Month 1, and at the commencement and conclusion of Month 5, were all significantly higher when compared to Baseline. However, no significant difference was found between individual scores recorded whilst undertaking shift work.

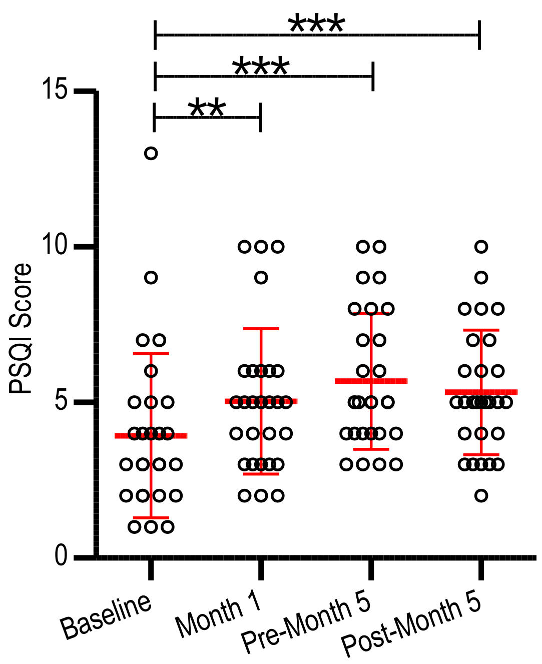

Figure 3.6: PSQI questionnaires, scored out of 21, were completed by each participant at Baseline (day 0, no shift work), Month 1 (approx. day 50, end of 1st month of shift work), Pre-Month 5 (approx. day 140, commencement of 5th month of shift work) and Post-Month 5 (approx. day 165, end of 5th month of shift work). Baseline differed significantly from Month 1 (**, p<0.01), from Pre-Month 5 (***, p <0.005) and from Post-Month 5 (***, p <0.005). Data presented as mean ± SD, n = 28. Significance determined using one-way ANOVA.

3.2 Activity

Activity levels were recorded for graduate paramedics during their first six months of paramedic practice. A significant (p =0.0097) increase in the percentage of time spent sedentary was observed across the study protocol (Figure 3.7A). This coincides with a significant (p =0.0026) decline in the percentage of time spent undertaking light exercise across the same period (Figure 3.7B). However, no significant (p =0.48) change was observed in the percentage of time undertaking MVPA. Also, no significant (p =0.13) change was observed in the average number of steps recorded per day (Figure 3.7D).

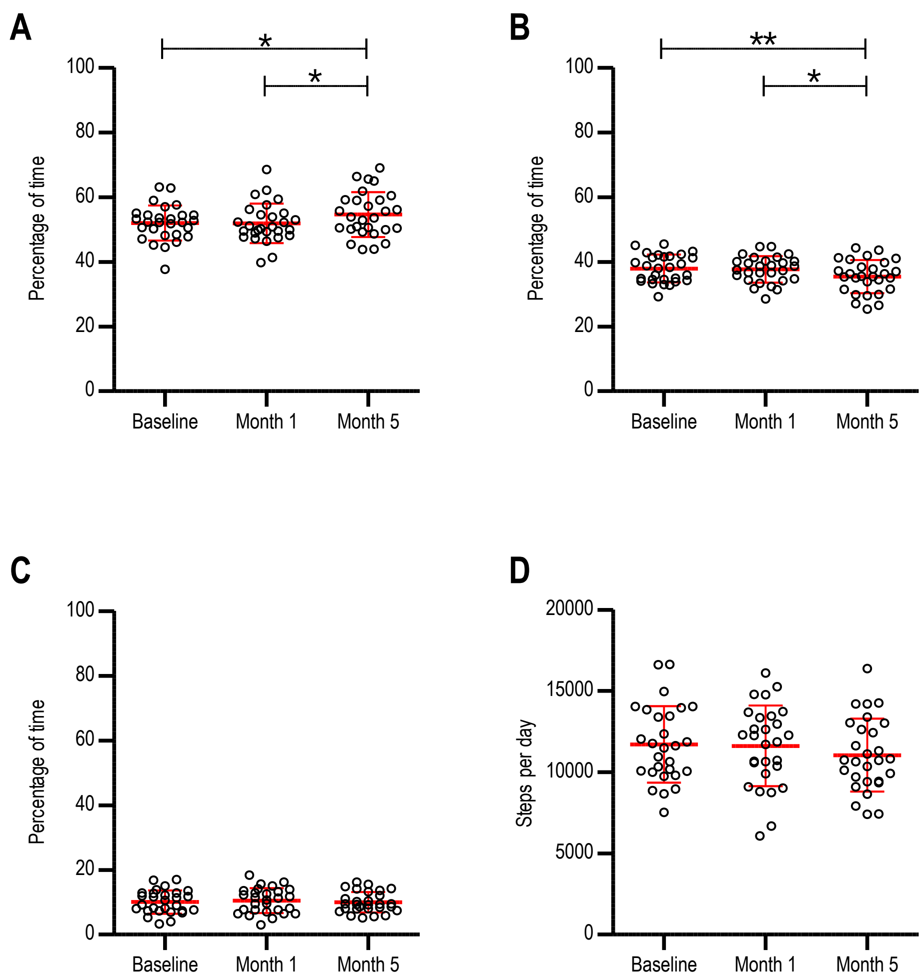

Figure 3.7: Each pane above illustrates 25-day mean activity data for participants at Baseline (non-shift work), Month 1 (1st month of rotational shift work) and Month 5 (5th month of rotational shift work). Data recorded continuously using Actigraph GT9X Link monitoring

devices. (A) Percentage of time spent sedentary (*indicating p <0.05). (B) Percentage of time spent undertaking light exercise (**indicating p <0.01 and *indicating p <0.05). (C) Percentage of time spent undertaking moderate to vigorous exercise. (D) Steps per day. Data presented as mean ± SD, n = 28. Significance determined using one-way ANOVA.

3.3 Health

Metrics of metabolic health were obtained at Baseline, at the end of Month 1, and pre and post the Month 5 assessment period.

3.3.1 Weight and waist circumference

Weight (*p* =0.071) did not change across the six-month study protocol (Figure 3.8A). However, waist circumference increased significantly (*p* =0.008) from the conclusion of Month 1 to the conclusion of Month 5 as shown in Figure 3.8B.

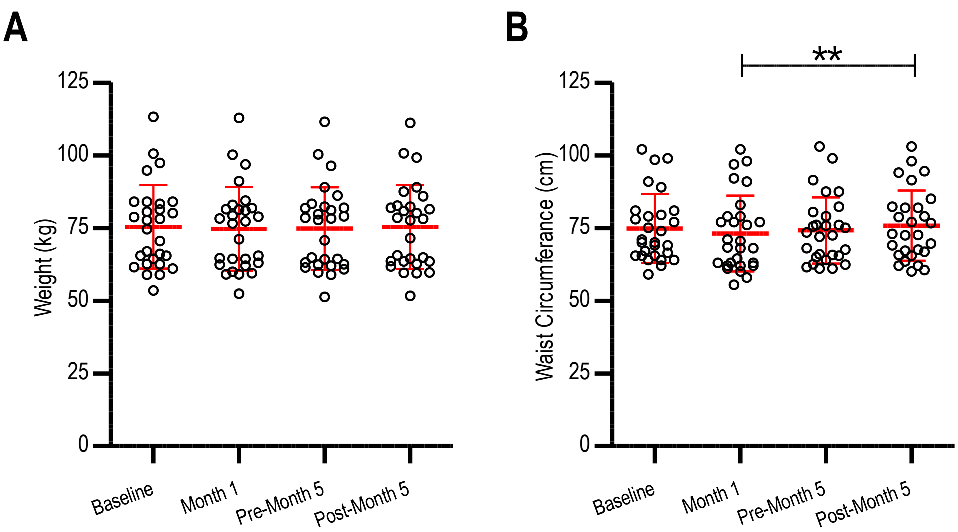

Figure 3.8: (A) Average weight and (B) average waist circumference recorded across the first 6 months of ambulance work (**indicating p <0.01). Measurements were obtained for each participant at Baseline (day 0, no shift work), Month 1 (approx. day 50, end of 1st month of shift work), Pre-Month 5 (approx. day 140, commencement of 5th month of shift work) and Post-Month 5 (approx. day 165, end of 5th month of shift work). Data presented as mean ± SD, n = 28. Significance determined using one-way ANOVA.

3.3.2 Cardiovascular

While there was evidence of a change in Resting Heart Rate (*p* =0.021), post-hoc analysis showed no difference between any of the assessment points and Baseline (Figure 3.9A). The estimated VO_2max increased significantly (*p* <0.001) between Baseline and Month 5 (pre and post *p* =0.013, *p* <0.001) (Figure 3.9B). No significant changes were noted for systolic (*p* =0.33) or diastolic (*p* =0.98) blood pressure across the study population as shown in Figure 3.9C and D respectively.

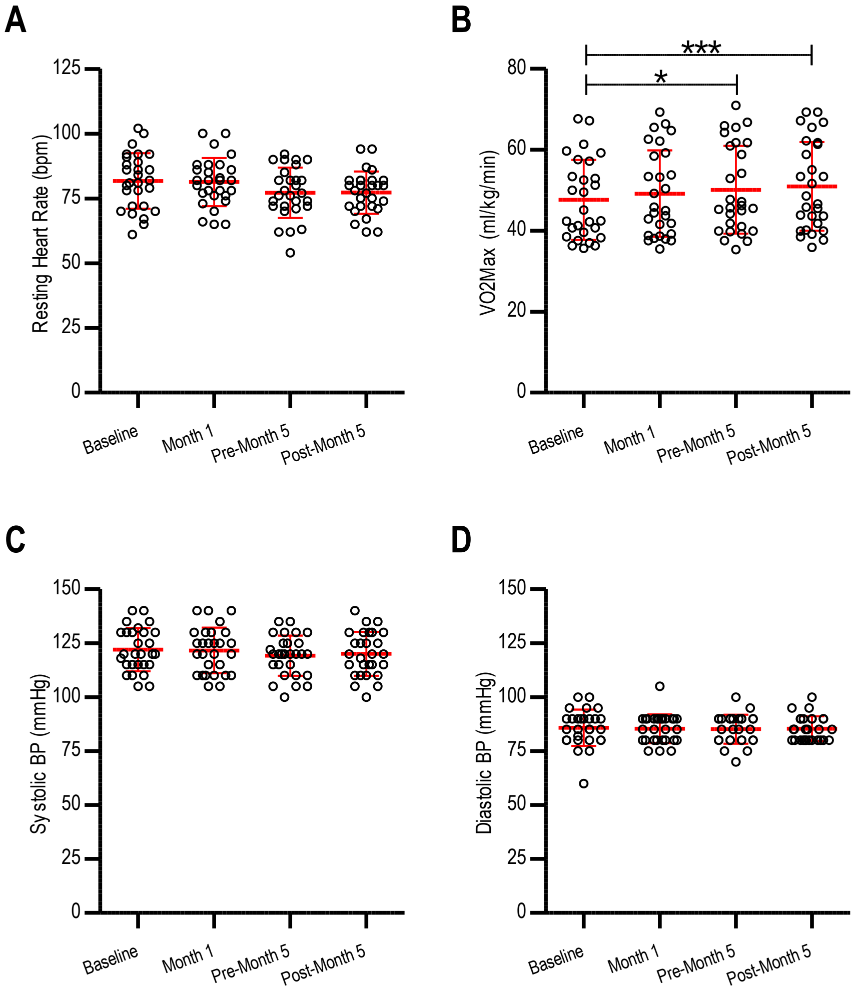

Figure 3.9: (A) Average resting heart rate. (B) Average estimated VO_2max (***indicating p <0.005 and *indicating p <0.05). (C) Systolic Blood Pressure. (D) Diastolic Blood Pressure. Measurements were obtained for each participant at Baseline (day 0, no shift work), Month 1 (approx. day 50, end of 1st month of shift work), Pre-Month 5 (approx. day 140, commencement of 5th month of shift work) and Post-Month 5 (approx. day 165, end of 5th

month of shift work). Data presented as mean ± SD, n = 28. Significance determined using one-way ANOVA.

3.3.2 Metabolic

Baseline measures of BG were within the normal limits for a healthy population (5.0 ± 0.6 Mmol/L). There were no significant changes in fasting BG levels (*p* =0.64) during the protocol.

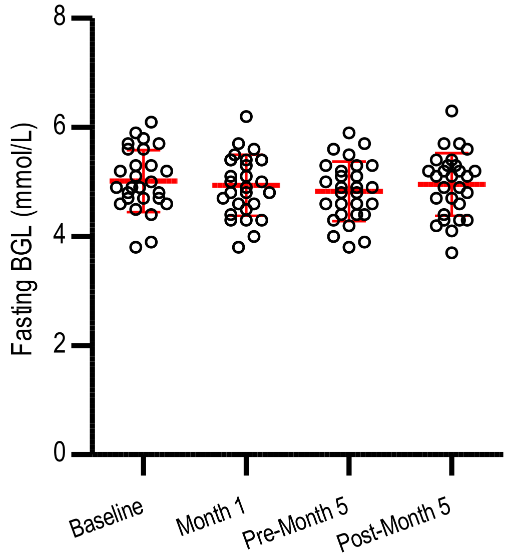

Figure 3.10: Average Fasting BG levels for participants across the study protocol. Measurements were obtained for each participant at Baseline (day 0, no shift work), Month 1 (approx. day 50, end of 1st month of shift work), Pre-Month 5 (approx. day 140, commencement of 5th month of shift work) and Post-Month 5 (approx. day 165, end of 5th month of shift work). Data presented as mean ± SD, n = 28.

3.4 Perceived stress

Stress scores, measured by the International Stress Management Association of UK National Stress Awareness Day (NSAD) questionnaire, increased significantly (*p* =0.001) during the first six months of paramedic practice (Figure 3.11). Score obtained at the conclusion of Month 1 were not significantly different to Baseline (*p* =0.13), however Pre Month 5 (*p* <0.01) and Post Month 5 (*p* <0.01) were significantly higher that at the commencement of the protocol.

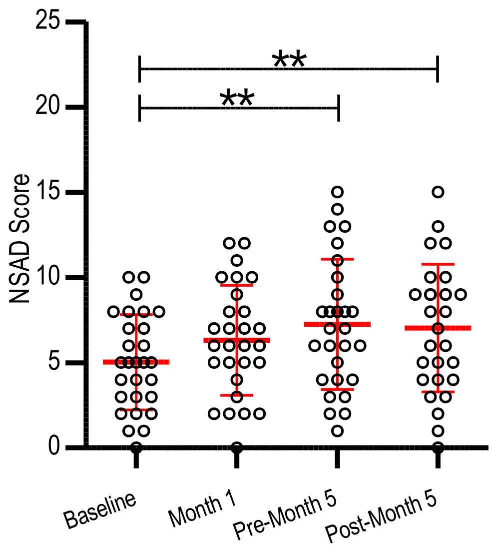

Figure 3.11: Stress score for each assessment period during the first 6 months of ambulance work. The National Stress Awareness Day (NSAD) questionnaire gives a subjective stress score out of maximum of 25, obtained for each participant at Baseline (day 0, no shift work), Month 1 (approx. day 50, end of 1st month of shift work), Pre-M5 (approx. day 140, commencement of 5th month of shift work) and Post-M5 (approx. day 165, end of 5th month of shift work). **indicating $p < 0.01$. Data presented as mean ± SD, n = 28. Significance determined using one-way ANOVA.

4.0 Discussion

4.1 Overview of Findings

The first aim of this study was to examine if there were chronic changes in measures of sleep quality and quantity as graduate paramedics commenced their first five months of shift work. Sleep was assessed across three 25-day periods at Month 0 (Baseline), Month 1 and Month 5. This period encompassed shift work days and non-working days (RDOs). Consequently, data is presented as a 25 day mean, as well as isolating RDO data to assess if non-work sleep patterns were chronically impacted by shift work.

There was no change in Sleep Efficiency or sleep duration during the first five months of shift work in this cohort of graduate paramedics. There was however an increase in the total amount of sleep (TST) and number of sleep episodes during the assessment periods at Month 1 and 5. Significantly shorter Sleep Duration was also observed on final (pre-work) RDOs, supporting anecdotal reports of tiredness amongst paramedics on their first day back at work. The forced nature of rotational shift work certainly altered sleep / wake patterns. However, results obtained did not support the hypothesis that rotating shift work leads to diminished sleep quality and quantity in early career paramedics.

The second aim addressed in this study was to assess if early risk factors for major medical conditions presented in the first five months of ambulance work. This study found an increase in the percentage of time spent sedentary, a reduction in light-intensity exercise, and an increase in waist circumference; all of which are associated with increased risk of cardiometabolic disease and support the second hypothesis of the research.

4.2 Sleep Quantity

Sleep Duration and Total Sleep Time (TST) were assessed across each 25-day assessment as measures of sleep quality. At Baseline, prior to commencing shift work, the average Sleep Duration of graduate paramedics was 6.65 ± 0.72 hours. During shift work, the 25-day mean Sleep Duration for Month 1 was 5.87 ± 0.92 hours and 6.13 ± 0.79 hours for Month 5 (Figure 3.3A). This reduced mean Sleep Duration across Month 1 and Month 5 is attributable to the increased Sleep Episodes (Figure 3.1B). To assess chronic changes in sleep patterns, it is more contextual to examine Sleep Duration only during RDOs as this removes the influence of disrupted sleep patterns during shift work. During RDOs in Month 1 and Month 5, the average sleep duration was 6.78 ± 0.87 hours and 6.75 ± 0.78 respectively (Figure 3.3B). In evaluating these data, it is important to note that actigraphy tends to overestimate total sleep due to the inability of the device to identify when a non-sleeping individual lies motionless in bed (Paquet et al., 2007). This is not such a concern in this research as the comparison is being drawn between the same individuals' pre-shift work and during shift work phases of their lives. However, the Sleep Duration data obtained here may actually be slightly overestimating the sleep quantity that graduates are having across the entire protocol. This is concerning, as results for all assessments are below international recommendations that healthy adults obtain between 7-9 hours of sleep per night (Hirshkowitz et al., 2015, Badr et al., 2015). Baseline data showed that this cohort of graduates were sleeping for less than the recommended 7 hours, which remained unchanged across the protocol. Short Sleep Duration is known to be a contributing factor to diabetes (Gangwisch et al., 2007), obesity (Cappuccio et al., 2008), heart disease (Dominguez et al., 2019), cognitive decline (Marquié et al., 2015) and Alzheimer's disease (Mawuenyega et al., 2010). The short Sleep Duration results obtained in this study further support published research identifying a high percentage (up to 72%) of paramedics who report poor sleep leading to fatigue (Sofianopoulos et al., 2011, Courtney et al., 2012). The differentiating factor is that in this study Sleep Duration was measured objectively via the actigraph, whereas the published research highlighted utilised subjective questionnaires to assess Sleep Duration, which often lead to bias and over- or underestimation of certain responses (Buysse et al., 2008, Lauderdale et al., 2008).

In examining Sleep Duration immediately after night duty (Figure 3.3C), graduates slept for 4.2 ± 1.3 hours in Month 1 and 4.4 ± 1.4 hours in Month 5. Kecklund and Axelsson (2016) completed a meta-analysis of case-controlled, prospective and randomised sleep research designs involving shift workers from all fields published between 2006 and 2016. Only seven suitable publications were identified, further stressing the need for more quantifiable research of shift workers. The authors of this meta-analysis calculated the average Sleep Duration post night duty as 5 hours and 51 minutes, with no standard deviation published in their review. Graduate paramedics involved in this project were found to be sleeping for shorter periods than reported in the literature, possibly leading to lingering feelings of tiredness across their rest days and supporting the PSQI results discussed above.

On RDOs, rotational shift workers are known to 'catch up' by sleeping longer (Alward and Monk, 1990, Escriba et al., 1992). However, when data from all RDOs in this study were examined (Figure 3.3B), no statistically significant difference in Sleep Duration was observed. However, Sleep Duration on the final rest day was shorter than the other rest days (Figure 3.3D), indicating that the first two RDOs are likely associated with longer sleep, supporting the 'catch up' notion. The final RDO Sleep Duration was particularly short in Month 5 (5.72 ± 1.06 hours) compared to Month 1 (5.99 ± 1.16 hours) and Baseline (6.65 ± 0.72 hours). Indeed, both months of shift work produced a Sleep Duration of less than six hours for this sleep period, significantly less than the 25-day mean recorded at Baseline. Whilst the actigraph does not evaluate sleep stages in the way PSG does (Albu et al., 2019), limited sleep of this duration is known to restrict time spent in the REM phase of sleep, leading to an inhibition of high-performance functioning and reduced productivity (Ohlmann and O'Sullivan, 2009). Shorter Sleep Duration has also been found to correlate with subjective opinion of poor sleep (Lauderdale et al., 2006), supporting anecdotal reports from paramedics of poor sleep on the last RDO before returning to work. This also indicates an area where ambulance services can support graduate paramedics with sleep education early in their careers in an attempt to rectify some of the issues observed in study.

TST across the 25 day periods increased significantly by 4.7% in Month 1, and this increase was still evident during in Month 5 (Figure 3.1A). Considering that Sleep Duration did not change significantly on RDOs, the increase in TST can be attributed to additional short bouts of sleep or 'napping', pre- and post-night shift which did not occur during Baseline. This is also supported by the increased number of Sleep Episodes shown in Figure 3.1B. In considering that the graduates were sleeping more across the months of shift work, we note that during the Baseline assessment graduates were working an average week of between 38 and 40 hours. When shift work commenced, this increased to an average working week of between 40.25 hours and 42 hours (Vu, 2016) and potentially longer working hours with overtime. Research involving other healthcare workers indicates that shift work of more than 40 hours per week is associated with increased levels of fatigue (Scott et al., 2006). Specifically, rotational shift work leads to sleep debt (Frakes and Kelly, 2007a) and an accumulation of fatigue (Niu et al., 2011). Therefore, it is likely that these graduate paramedics are now feeling more tired and needing more sleep due to a combination of increased working hours and exposure to rotational shift work. This is also supported by the results obtained from the PSQI questionnaire (discussed below), which includes specific questions around 'trouble staying awake' and 'enthusiasm to get things done'. The subjective scores obtained via this questionnaire during the months of shift work were significantly worse than Baseline (Figure 3.6), supporting the notion that graduates felt fatigued, and needing more TST to function appropriately during Month 1 and Month 5.

4.3 Sleep Quality

Sleep quality was assessed by measures of Sleep Efficiency and disturbance (NoA and WASO). Sleep efficiency and WASO were reported as a percentage of time, whilst NoA was averaged per hour.

There was no change in Sleep Efficiency during either Month 1 or Month 5 of shift work compared to Baseline. Sleep Efficiency during RDOs was consistent with the 25-day mean, as was the final RDO data across both months. In contrast, Sleep Efficiency scores for the sleep episode immediately after night duty showed a high degree of variability in Month 1 (SD ± 9.3%) and Month 5 (SD ± 9.7%). Comparing this to the 25-day mean Sleep Efficiency scores for the same months (SD ± 6.2% and ± 5.2% respectively), far less variation is evident. With the high variability observed in Sleep Efficiency scores for this daytime sleep, it appears that some graduates may have adapted better to sleeping during the day than others. These results are supported by research within other emergency services that found poor quality daytime sleep was common in up to 70% of respondents (Fekedulegn et al., 2016). Additionally, daytime sleep duration was found to reduce as exposure to shift work increased in novice police officers (Lammers-van der Holst et al., 2006), but individual variability remained (Lammers-van der Holst et al., 2016). Therefore, this shorter and occasionally poorer quality daytime sleep observed in our study has possibly contributed to feelings of tiredness and fatigue identified in the graduates.

To further assess sleep quality, raw WASO data was collected using the actigraph monitor and recorded as minutes of awakening across a period of sleep. As sleep length is variable, WASO data presented is converted to a percentage of time awake across each sleep episode. Likewise, NoA is presented as awakenings per hour to be independent of sleep length. From this study, we found the percentage of WASO at Baseline (20.75%) was consistent with published research using wrist-worn actigraphy from other study populations. Lee and Hsu (2012) studied a cohort of new mothers to identify changes to sleep patterns. They found that 20.0 ± 12.0% was a normal WASO percentage in their study population, whilst Hoelscher and Edinger (1988) identified a WASO percentage of 36% or more as indicative of moderate insomnia. In examining NoA data as an additional measure of sleep quality, it is important to note this metric is a measure of arm movement and does not necessary indicate being 'awake'. Data from this study is consistent with published norms of periodic limb movement (PLM) of <5 per hour (Hornyak et al., 2006) which are associated with normal movements during sleep.

There was no change from Baseline in the 25-day mean WASO or NoA data during either Month 1 or Month 5 (Figures 3.4A and Figure 3.5A respectively). In examining WASO data immediately after night duty for Month 1 and Month 5, outliers are clearly present (Figure 3.4C). These outliers support earlier results indicating that a small number of graduates may not have adapted well to daytime sleep. However, for this same sleep period, a significantly lower number of NoA per hour were recorded in both Month 1 and Month 5 (Figure 3.5C). This data indicates restful sleep (possibly attributable to exhaustion) following a long night shift. Published research further supports this assertion. Tucker et al. (2017) found that doctors who worked shifts more than 12 hours in duration were five times more likely to report fatigue, whilst Dembe et al. (2005) found that for every 2 hours worked per day over 8 hours was associated with a higher rate of fatigue-induced injuries. Whilst a consensus definition of fatigue is absent, research concludes that longer shift lengths lead to a decrease in performance and vigilance associated with tiredness (Scott et al., 2006). In considering fitness for duty, AV utilises the following definition of fatigue: *"A physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an ambulance or safely perform related duties"* (Vu, 2016), although the measurements of fatigue are not standardised and difficult to quantify. Fatigue scoring was beyond the scope of this project, but further research in this field attempting to quantify fatigue to support the objective data gathered is warranted.

From the sleep data obtained in this project, it is clear that the rotational roster structure is altering pre-existing sleep patterns observed in this study. We recorded an increase in the number of individual Sleep Episodes from napping pre- and post-night shift, and we observed an increase in the Total Sleep Time across the shift work months. Sleep Duration during shift work was consistent with Baseline, but the final RDO had a shorter sleep period, possibly leading graduates to feel tired on their first day at work. The overall impact on sleep quality appears minimal. As discussed, we observed no change to sleep efficiency or WASO across the protocol. The only changes to the NoA scores were observed for the sleep period after night duty, and these scores indicated a less disturbed sleep than for other sleep periods in the protocol. It is probable that exhaustion after a long night shift is the cause of this, but the result is that the sleep has become more effective. Whilst restful, this sleep period is too short and also contributes to accumulated fatigue. In fact, we found that all sleep periods were too short, and potentially put graduates at an increased risk of health issues resultant from short sleep duration.

4.4 Subjective Data

Subjective scoring of sleep has long been a mainstay of environmental sleep research (Akerstedt, 2003, Axelsson et al., 2004, Courtney et al., 2012, Frakes and Kelly, 2007a, Haddock et al., 2013, Patterson et al., 2010, Pilcher et al., 1997, Son et al., 2008, Takeyama et al., 2009). In this study, the PSQI was utilised as a subjective score of sleep quality and quantity to complement objective data gathered from the actigraph. As shown in Figure 3.6, sleep scores obtained from the PSQI increased across the study protocol. This indicates that graduates felt their sleep quality was poorer than Baseline. The shorter Sleep Duration recorded on the final RDO in Month 5 (Figure 3.3D) and the slight reduction in TST (Figure 3.1B) for Month 5 (compared to Month 1), suggest that graduates are likely to be experiencing feelings of chronic tiredness throughout this final month of shift work prior to their first leave block. This may provide scope for the ambulance service to consider if five consecutive months of rotational shift work is appropriate for new graduate paramedics.

The NSAD stress questionnaire (Figure 3.11) was also utilised throughout the protocol. This questionnaire includes subjective questions about stress and energy levels and produced a similar pattern of data to the PSQI. The increase in stress scores obtained pre- and post- Month 5 indicate that graduates were feeling significantly more stressed and fatigued at this stage of their careers when compared to Baseline. Also of note, the similarity in data response from these two separate questionnaires suggest that the PSQI may be both a subjective response to fatigue and stress as well as sleep quality and quantity.

4.5 Activity

Activity levels were assessed to investigate whether shift work affected sedentary behaviour and exercise. Exercise intensity was determined by the Actilife software using the Freedson Adult algorithm (Freedson et al., 1998), which determines the amount of movement in each 60-second epoch. Based on set criteria, either sedentary, light, or moderate to vigorous physical activity (MVPA) is scored. Sedentary behaviour is defined as any waking behaviour resulting in low energy expenditure whilst in a sitting or reclining position (Barnes et al., 2012). Light and MVPA levels are based on energy expenditure in a 60-second period, with MVPA considered an 'exertional' level of activity (Gibbs et al., 2015). Activity calculations are undertaken for periods of time when the participant is not deemed 'asleep' and data is discussed as 25-day means for each assessment period.

At Baseline, graduate paramedics exhibited 51.9% sedentary time, light intensity exercise for 38.2% of the time, and were undertaking MVPA 9.9% during their waking time. When converted to minutes of activity per week, this equates to an average MVPA of 299 ± 114 minutes at Baseline. Comparing this to National Health and Medical Research Council (NHMRC) recommendations (Egger et al., 2001) and WHO activity guidelines (World Health Organization, 2010), the subject group were exceeding the minimum recommendation of 150 minutes per week of MVPA. This data indicates that graduate paramedics in this research project were undertaking activity levels above population expectations at the commencement of their ambulance career.

During month 1 and 5 there was a shift in the activity levels of the graduates. Of concern was a 5.6% increase in sedentary behaviour observed in Month 5 compared to Baseline (Figure 3.7A), corresponding with a decrease in light intensity exercise (Figure 3.7B). Research in this area, specifically examining shift workers undertaking rotational rosters, report mixed findings. For example, many studies report a decrease in available time for exercise (Kaliterna et al., 2004, Peplonska et al., 2014), or find a shift in activity habits leading to increased light intensity exercise and decreased sedentary time (Loprinzi, 2015). Other studies show shift workers exhibit sedentary behaviour levels twice that of daytime workers (Pietroiusti et al., 2010). Some of the variation in these findings may result from different methods used to assess physical activity. The Kaliterna et al. (2004), Pietroiusti et al. (2010) and Peplonska et al. (2014) studies utilised subjective questionnaires to assess physical activity, while Loprinzi (2015) used accelerometry. The Loprinzi (2015) research is most similar to this study in utilising an actigraph to assess physical activity supported by self-reported data from questionnaires. However, this research also highlights a limitation in the literature where data recording occurs over a relatively short period of time. Loprinzi (2015) assessed activity data from a minimum of four days (no maximum wear time reported), finding that rotational shift workers exhibited less sedentary time, more light intensity exercise and more MVPA when compared to regular daytime workers. When comparing published literature, variables such as the different types of shift work with different roster schedules reported make definitive conclusions difficult.

As discussed earlier, TST increased across the protocol due to the increased work hours and increased levels of fatigue. From this, it would also be reasonable to expect an increase in sedentary time during Month 1 as the graduates adapt to shift work whilst exhibiting increasing signs of fatigue. This would be in line with literature that shows experienced shift workers spend 4.3% more time whilst at work in sedentary activity compared to daytime workers (Hulsegge et al., 2017). However, no significant change in sedentary activity nor light exercise intensity was observed for Month 1 compared to Baseline. We speculate that during this first month of working on an operational ambulance, the new graduates are utilising their free time at work to familiarise themselves with equipment and undertake practical exercises to improve their confidence. This is supported by Lynch and Buckner-Hayden (2010) who discuss new employees needing extra time and guidance to complete tasks, whilst Pointer (2001) shows on-the-job training of new emergency medical technician (EMT) recruits often occurs when not allocated to a callout.

Additionally, research shows that physical activity is linked to levels of perceived stress (Aldana et al., 1996). In this research, the graduates' perception of stress during Month 1 did not differ significantly from Baseline, as evident by NSAD stress scores shown in Figure 3.11, although a significant increase in these scores from Baseline is observed at the beginning and end of Month 5. Therefore, the graduates are possibly more active on non-work days/RDOs during Month 1 as they do not feel significantly more stressed at this stage of their career. As fatigue and stress builds towards Month 5, and confidence in their work ability grows, it is likely that the graduates are now using their free time at work and on RDOs to rest, which may explain the decline in light-intensity exercise and increase in sedentary activity. This supports data discussed earlier suggesting that the accumulation of fatigue in Month 5 causes altered sleep patterns.

Whilst fatigue accumulation is a factor in Month 5, we observed no change in 25-day mean MVPA data (292 ± 90 minutes) in this assessment (Figure 3.7C). Despite increased sedentary time, graduates were still achieving above the recommended 10,000 steps per day (Brown et al., 2006). This goal originated with Japanese walking groups several decades ago and has been shown to improve health in adults (Tudor-Locke and Bassett, 2004). In our study, participants were completing an average of 11713 ± 2358 steps per day at Baseline, which had fallen slightly to 11050 ± 2249 by the end (Figure 3.7D). This 6% decline probably corresponds to the decline in light intensity exercise reported earlier. However, the steps per day and MVPA measures still exceed international (World Health Organization, 2010) and Australian (Egger et al., 2001, Brown et al., 2006) recommendations, indicating that graduates are maintaining similar levels of exertional physical exercise to their pre-shift work lives. This may mitigate some of the chronic disease risks associated with shift work.

No published research specifically examines activity in paramedics utilising this method of assessment. In looking at comparative studies of other healthcare workers working a rotating roster, contemporary research by Roskoden et al. (2017) studied activity levels in 23 nurses working rotating days, evening and nights shifts (working hours not reported). This study found no difference in overall physical activity levels between nurses on shift work, versus clerical staff in the hospital working day shift only. Interestingly, this study found that during the shift, nurses exhibited lower levels of physical activity, but this was compensated by an increase in physical activity during non-work time. Our study shows that that ongoing shift work (>1 month) is leading to a more sedentary lifestyle and reduced light intensity exercise amongst graduate paramedics when 25-day mean data is examined. However, we are not able to determine if there was a change in exercise habits during days of shift work versus RDOs and this will require further research in this field.

For the graduates undertaking this study, who already exhibit pre-shift work levels of physical activity exceeding international recommendations (Egger et al., 2001, Brown et al., 2006, World Health Organization, 2010), this may not be too concerning. However, should this trend in the data continue across subsequent months and further into their careers, the negative health implications associated with increased sedentary time (Tremblay et al., 2011, Owen et al., 2014) may lead to a higher prevalence of chronic medical conditions amongst these paramedics. Also, for new graduates commencing shift work who have low levels of pre-shift work activity, there may be a greater impact. Activity may decrease further leading to increased disease risk or accelerated disease progression.

4.6 Health

Metrics of health and wellbeing were assessed at regular intervals throughout the protocol to investigate if early risk factors for cardiovascular disease and metabolic disorders could be identified in the first five months of rotational shift work.

At the commencement of the study, the graduates exhibited an average weight of 75.4 kg (± 14.3 kg) and had an average body mass index (BMI) of 25.19 kg/m2, placing them in the overweight category (>25 to 30 kg/m2) as defined by the Australian national standards (National Health Medical Research Council, 1997). Waist circumference increased significantly from the conclusion of Month 1 (73.0 ± 12.9cm) to the end of the protocol (75.8 ± 12.1cm) as shown in Figure 3.8B. Although small, such changes within the first six months of shift work are concerning. WHO recommendations for prevention of metabolic complications suggest that waist circumference of more than 102cm for men and 88cm for women places an individual at increased risk (Nishida et al., 2004). Both groups of male and female graduates in this study were below these recommendations, however the increase occurred without a change in body weight (Figure 3.8A), suggesting a decline in skeletal muscle mass. Increasing waist circumference, independent of body mass index (BMI) change, is indicative of increased visceral adipose tissue (Janssen et al., 2002) and has well-established links to increased risk of cardiometabolic disease and is a strong indicator of insulin resistance (Després et al., 2008, Arsenault et al., 2007, Abarca-Gómez et al., 2017). A possible reason for this could be change in appetite regulation induced by altered sleep. Whilst this study did not assess dietary intake, alterations in sleep patterns can increase the appetite–stimulating hormone ghrelin. Many studies have shown that altered sleep patterns - most likely through circadian misalignment - can result in increased appetite for energy-dense foods (Qian et al., 2018), consumption of larger portion sizes (Esquirol et al., 2009) and an appetite for foods higher in fat, sugar and salt (de Assis et al., 2003; Heath et al., 2012). Thus, shift work is a concerning risk factor for weight gain (Proper et al., 2016). Although weight gain was not observed in this study, the impacts of altered sleep patterns reported earlier may lead to weight gain amongst this group of paramedics as they progress in their careers. Further research conducted by Healy et al. (2008) examined (amongst other indicators of metabolic health) exercise intensity and waist circumference of 169 Australian diabetics. Their results conclude that waist circumference is highly correlated to time spent sedentary, regardless of time spent undertaking MVPA (Healy et al., 2008), consistent with results observed in our study.

No changes in fasting BG levels were observed across the protocol (Figure 3.10), however BG levels would only be expected to increase during later stages of insulin resistance (Martin et al., 1992). Likewise, no changes were observed in systolic or diastolic blood pressure. Whilst daily fluctuations in blood pressure are normal (Cortelli et al., 1996), and even acute increases have been associated with sleep loss (Lusardi et al., 1999), sustained changes in blood pressure takes time frames longer than those involved in this study (Carter et al., 2012). In relatively healthy subjects, such as those involved in this study, markers of cardiovascular or metabolic disease are unlikely to present over the six-month protocol as these can take decades to develop. However, given that this study has shown an increase in waist circumference and associated increased sedentary time, this may indicate that the early risk factors of poor metabolic health are developing in graduate paramedics and warrants further longitudinal studies of such cohorts.

In looking at cardiovascular health, a 7.0% increase in VO_2max was observed at the conclusion of the protocol. The estimated VO_2max in this study was calculated from recovery HR following a 3-minute step test, a recommended evaluation of cardiorespiratory fitness in the absence of an exercise laboratory setting (Chatterjee et al., 2005), which has some known issues and limitations. During testing, a standard metronome is used, however stepping frequency within the tests is often variable (Santo and Golding, 2003). In this study, participants were given a period of time to relax prior to undertaking the step test. However, it was not possible to know if they had worked a full night shift prior to testing or had come in after a full night's sleep, so resting HR may have varied prior to testing which may have impacted VO_2max scores. There is some evidence of a reduction in resting HR, however post-hoc data analysis showed no difference between any of the assessment points and Baseline. Reduction in resting HR and recovery HR across the protocol suggests an increase in cardiovascular fitness, contrary to the increased sedentary time / decreased light exercise data discussed earlier, but supported by the maintenance of MVPA. Some research indicates that increased job stress, such as that which may be felt when starting a new career, may cause heart rate variability (Kang et al., 2004). Also, the graduates were maintaining a high level of MVPA and achieving above the recommended 10,000 steps per day despite having increased TST. This may suggest that they are attempting to maintain a pre shift work level of activity in a reduced amount of free time, which may increase cardiovascular fitness levels despite changes to body morphology. Ultimately our Resting HR and VO_2max results are inconclusive and difficult to explain without further research.

4.7 Strengths

This study used the validated actigraph GT9X Link (Sasaki et al., 2011, Hanggi et al., 2013, McVeigh et al., 2015, Rosenberger et al., 2016) to record sleep and activity data in graduate paramedics. This is the first study of its kind to use actigraph data of sleep and activity in paramedics over this extended timeframe. Most published research in the field of activity and sleep monitoring utilises seven days of data recording (Baranowski et al., 2008) to allow behaviour sampling on both week days and weekends. Our extending sampling protocol gathered far greater amounts of data, allowing small anomalies in sleep and activity to be absorbed.

The non-intrusive nature of the actigraph allowed graduates to sleep in their own beds and maintain normal day-to-day activities, allowing data to be gathered on work days as well as rest days, which has not been reported in the literature to date. The actigraph produced data that accurately indicates quality of sleep, beyond a questionnaire that reports time ‘in bed’ and a subjective opinion of sleep quality. This further highlights a strength of this research being the use of both objective and subjective data gathering techniques over a longer timeframe. Prior to this project, real-world gathering of objective data for operational paramedics has not been done in Australia, with only one publication assessing sleep of Australian paramedics via subjective questionnaires (Mahony, 2001).

4.8 Limitations

This research sought to assess changes in sleep patterns of early-career paramedics. A major limitation of this research was the absence of a control group to serve as a comparison to the graduates. To incorporate a control group of experienced paramedics would be difficult, as you would ideally need to utilise the second paramedic of the crew to ensure the same exposure to workload and rostering. However, this poses problems as the second paramedic may have varying experience and varying exposure to shift work. Additionally, this study did not assess if similar changes would be observed for employees commencing new employment in another health field with a shift work structure. Research from the nursing field indicates that the first five months of employment is an intense period of adaption often involving self-doubt, anxiety and a lack of confidence (Ortiz, 2016). Additional nursing research identifies the 12-month period as a landmark for a stable level of confidence (Duchscher, 2012), but no research is available that examines this initial period of paramedic practice. This highlights the importance of this project in filling a significant gap in paramedic-focused research, specifically the experience of new recruits starting in the paramedic workforce.

A further limitation existed in the inability to quantify the effect of external influences on sleep and activity, beyond shift work. Factors such as participants having young children or being exposed to stressful events are likely to impact on sleep and activity of graduate paramedics. However, as this is real-word research and not conducted in an artificial environment such as a sleep laboratory, this must be accepted. In this research the subjective questionnaires completed at Baseline went some way to scoring external stressors prior to shift work commencing, but the additional effects of these during shift work may need to be quantified via a rating scale or scoring mechanism in future research.

Roster variability must also be noted as a limitation in this research. Whilst the majority of participants worked a standard 10/14 roster (or variation involving a 12-hour afternoon shift in lieu of the first night shift) with four days working and four RDOs, several participants worked a modified roster of five days working and three RDOs. All rosters contained a minimum of 40.25 – 44 working hours per week and all involved a similar amount of night duty. Additionally, the nature of ambulance response means that the case load on any given shift is variable. Some shifts would see graduates working continuously, whilst other shifts may see extended periods of downtime allowing for rest. Furthermore, overtime at the end of shift was not reported and may have contributed to increased working hours for a small number of participants. This may have increased fatigue amongst a few participants, but the high number of graduates assessed is likely to compensate for these variances. Also, the extended period of time that graduates were monitored in this study reduced the impact of these unavoidable variables of emergency response research.

A further issue encountered was compliance with manually-entered sleep log times, which highlighted a limitation of the methodology. Participants were instructed to be as accurate as possible when recording in-bed and out-of-bed times, however poor compliance saw inconsistent entries. As discussed earlier, much of the existing data in paramedic practice is qualitative, relying on subjective measures such as questionnaires and recall to assess the impact of shift work on fatigue and health. The use of actigraphy in this research allowed high quality data for Sleep Efficiency, sleep disturbance and Sleep Duration. However, inconsistent sleep logs made statistically significant analysis of Sleep Latency impossible and therefore this metric was omitted from reported results. Whilst identified as a limitation, this actually highlights the robust nature of the other data reported and, due to sleep being undertaken in participants' own homes and over an extended period of observation, improvement in this area for future research is difficult.

4.9 Recommendations

Sleep hygiene education programs have been found to alleviate sleep problems in young adults and potentially instil long-lasting healthy sleep practices (Kloss et al., 2016, Gruber, 2017). Graduates undertake units of study during their undergraduate program to explore sleep education and techniques to achieve improved sleep quality, but this does not currently form part of the AV induction program. Results obtained in this study, particularly around sleep duration, indicate an area where ambulance services can support graduate paramedics with sleep education early in their careers. These sleep education programs have been shown to improve sleep duration (Trockel et al., 2011) and decrease sleep disturbance (Yang et al., 2011). This would be seen as a positive step in reducing the accumulated fatigue identified in this research, and potentially lead to increased longevity of employees.

AV have recently established partnerships with gyms and health centres allowing discounted rates for staff. This is vitally important, as research conducted by Han et al. (2019) found that an unhealthy lifestyle in nursing graduates was linked to higher staff turnover. Also, with the results obtained in our study - particularly the increased sedentary time and decreased light exercise - this positive initiative is seen as a further support for the health and wellbeing of paramedics within AV. Expansion of this program will allow paramedics to increase their MVPA and light exercise, both of which have been shown to reduce the prevalence of chronic medical conditions in the population (Ham et al., 2004).

Extensive work is being conducted by AV to improve roster structure and reduce fatigue. Results obtained in our research support literature showing that paramedic shift work leads to increased feelings of fatigue, associated health concerns and concerns about medical errors. We encourage AV to further explore fatigue-reducing roster options as a possible means of alleviating some of these concerns. Additionally, five consecutive months of shift work resulted in graduate paramedics in this study reporting increased metrics of accumulated fatigue. We observed that stress and fatigue scores, along with subjective score of poor sleep quality, peaked at the commencement and conclusion of Month 5. Further research is needed to assess whether this initial period of five consecutive months of shift work should be reduced to support the health of graduate paramedics by reducing their accumulated stress and fatigue.

5.0 Conclusion

This study is the first quantitative research to assess physiological changes in sleep patterns and activity levels of graduate paramedics undertaking a new career with shift work. The data suggests that shift work leads to more fragmented sleep patterns and increased physiological need for sleep. What is not clear is the consequences on job performance and the long-term implications for paramedic health. Subsequent research on the same group of paramedics several years into their careers may go some way to answering this question. Longitudinal research is also needed to examine if alterations to sleep patterns persist beyond their ambulance service employment.

It is concerning that early indicators of medical risk factors developed within the duration of our study. Further research involving larger cohorts over longer time frames is needed to assess if these risk factors develop into significant health issues later in a paramedic's career and life.

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Appendix 1

NSAD STRESS QUESTIONNAIRE

International Stress Management Association UK

Promoting stress prevention and well-being

Because everyone reacts to stress in his or her own way, no one stress test can give you a complete diagnosis of your stress levels. This stress test is intended to give you an overview only. Please see a Stress Management Consultant for a more in depth analysis.

Answer all the questions but just tick one box that applies to you, either yes or no. Answer yes, *even if only part of a question applies to you*. Take your time, but please be completely honest with your answers:

		Yes	No
1	I frequently bring work home at night		
2	Not enough hours in the day to do all the things that I must do		
3	I deny or ignore problems in the hope that they will go away		
4	I do the jobs myself to ensure they are done properly		
5	I underestimate how long it takes to do things		
6	I feel that there are too many deadlines in my work / life that are difficult to meet		
7	My self confidence / self esteem is lower than I would like it to be		
8	I frequently have guilty feelings if I relax and do nothing		
9	I find myself thinking about problems even when I am supposed to be relaxing		
10	I feel fatigued or tired even when I wake after an adequate sleep		
11	I often nod or finish other peoples sentences for them when they speak slowly		
12	I have a tendency to eat, talk, walk and drive quickly		
13	My appetite has changed, have either a desire to binge or have a loss of appetite / may skip meals		
14	I feel irritated or angry if the car or traffic in front seems to be going too slowly/ I become very frustrated at having to wait in a queue		
15	If something or someone really annoys me I will bottle up my feelings		
16	When I play sport or games, I really try to win whoever I play		
17	I experience mood swings, difficulty making decisions, concentration and memory is impaired		
18	I find fault and criticize others rather than praising, even if it is deserved		
19	I seem to be listening even though I am preoccupied with my own thoughts		
20	My sex drive is lower, can experience changes to menstrual cycle		
21	I find myself grinding my teeth		
22	Increase in muscular aches and pains especially in the neck, head, lower back, shoulders		
23	I am unable to perform tasks as well as I used to, my judgment is clouded or not as good as it was		
24	I find I have a greater dependency on alcohol, caffeine, nicotine or drugs		
25	I find that I don't have time for many interests / hobbies outside of work		
A yes answer score = 1 (one), and a no answer score = 0 (zero).	TOTALS		

Appendix 2

The Pittsburgh Sleep Quality Index (PSQI)

Instructions: The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions. During the past month,

1. When have you usually gone to bed? ______________
2. How long (in minutes) has it taken you to fall asleep each night? ______________
3. When have you usually gotten up in the morning? ______________
4. How many hours of actual sleep do you get at night? (This may be different than the number of hours you spend in bed) ______________

5. During the past month, how often have you had trouble sleeping because you…	Not during the past month (0)	Less than once a week (1)	Once or twice a week (2)	Three or more times week (3)
a. Cannot get to sleep within 30 minutes				
b. Wake up in the middle of the night or early morning				
c. Have to get up to use the bathroom				
d. Cannot breathe comfortably				
e. Cough or snore loudly				
f. Feel too cold				
g. Feel too hot				
h. Have bad dreams				
i. Have pain				
j. Other reason(s), please describe, including how often you have had trouble sleeping because of this reason(s):				
6. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?				
7. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?				
8. During the past month, how much of a problem has it been for you to keep up enthusiasm to get things done?				
	Very good (0)	Fairly good (1)	Fairly bad (2)	Very bad (3)
9. During the past month, how would you rate your sleep quality overall?				

Component 1	#9 Score	C1______
Component 2	#2 Score (≤15min=0; 16-30 min=1; 31-60 min=2, >60 min=3) + #5a Score (if sum is equal 0=0; 1-2=1; 3-4=2; 5-6=3)	C2______
Component 3	#4 Score (>7=0; 6-7=1; 5-6=2; <5=3)	C3______
Component 4	(total # of hours asleep)/(total # of hours in bed) x 100 >85%=0, 75%-84%=1, 65%-74%=2, <65%=3	C4______
Component 5	Sum of Scores #5b to #5j (0=0; 1-9=1; 10-18=2; 19-27=3)	C5______
Component 6	#6 Score	C6______
Component 7	#7 Score + #8 Score (0=0; 1-2=1; 3-4=2; 5-6=3)	C7______

Add the seven component scores together ________ **Global PSQI Score** ________

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